A FLIGHT AT SUNSET. THE HANRIOT MONOPLANE IN MID-AIR

Monoplanes and Biplanes

THEIR DESIGN, CONSTRUCTION AND OPERATION

The Application of Aerodynamic Theory with a Complete Description and Comparison of the Notable Types

By

GROVER CLEVELAND LOENING. B.Sc., A.M.

278 ILLUSTRATIONS

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PREFACE

AVIATION has now advanced to the stage where a practical exposition of the subject is widely demanded. Many so-called "popular" books have been written, and contain much that attracts the attention of the average man, but little if anything that appeals to the more serious student of the subject. On the other hand, many valuable treatises have been written, but of so scientific and mathematical a nature that they are almost unintelligible to all but a few technical men; and in many cases it must be acknowledged that mathematics often lead to conclusions that are wholly at odds with the actual results of practice.

In this book, therefore, the author has made it his purpose to present the subject of "the aeroplane" in a manner that is at once intelligible and of interest to the average man, as well as of value to the more learned student.

Much of the work involved in the writing of this book was done in fulfillment of the requirements for the degree of Master of Arts at Columbia University. This work, largely in the nature of research, was under the direction of Dr. Charles C. Trowbridge, of the Department of Physics, to whom the author is naturally indebted for many valuable suggestions and much friendly aid.

The author's thesis accepted for this degree was published serially in the Scientific American Supplement, Nos. 1816-1822, inclusive, and forms the nucleus of this work. But the progress in the subject is so rapid that more than twice as much new matter has been added.

After an historical introduction in which the inestimable value of the work of Langley, Lilienthal and Chanute is pointed out, the design of aeroplanes is taken up. The theory of Aerodynamics is given as simply and completely as possible, and the fundamental principles are everywhere fully explained and emphasized. At the end of this section is given a complete example of the design of an aeroplane, which should prove of particular value to those actively engaged in aeroplane construction.

The monoplanes and biplanes in their various forms are then considered. Detailed descriptions of virtually all of the present successful types are given, supplemented by photographs and diagrams reproduced to the same scale, thus at once enabling a graphic comparison. Many of the types are changed from time to time and the data is in many cases unreliable, but the author has spared neither time nor effort to render this section as exact as he was able to. Were the leading machines here described not to remain substantially the same for years to come, they should, nevertheless, prove of permanent value in that they represent distinct types with which concrete results were first obtained.

In the last part of the book, the leading types are compared and discussed, and from the results of actual practice conclusions are drawn, enabling the lines of probable future development to be pointed out. This section will prove of interest to almost every one, as it is the author's experience that the knowledge of this subject possessed by the average person is far greater than most writers suppose.

The numerous tragic and in many cases avoidable accidents constitute, probably, one of the greatest detriments to the progress of aviation. Their causes, and as far as possible with the meagre knowledge available, the means for their prevention, are considered in this section; and the fact that aviation is reasonably safe can unquestionably be concluded therefrom.

The closing chapter of the book deals with the "variable surface aeroplane", a development which the author believes to be the next great step forward in the rapid progress of aviation.

The author wishes also to express his appreciation of the valuable favors, information and assistance which he has received from Prof. Wm. Hallock of Columbia University, Prof. Carl Runge of Goettingen, Mr. Wilbur Wright, Mr. A. M. Herring, and Mr. Ernest L. Jones, editor of "Aeronautics".

The kind offices of Messrs. Stanley Y. Beach and John J. Ide have greatly facilitated the author's work.

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PART I.

THE DESIGN OF AEROPLANES

HISTORICAL INTRODUCTION—AERODYNAMIC THEORY—AEROPLANE CALCULATIONS

INTRODUCTION

CHAPTER I

IN HIS immortal "Rasselas," Dr. Samuel Johnson says, "instead of the tardy conveyance of ships and chariots, man might use the swifter migration of wings, the fields of air are open to knowledge, and only ignorance and idleness need crawl upon the ground." This fanciful prophecy has almost been realized in fact.

Over one thousand aeroplanes have successfully flown, covering an aggregate distance of at least 150,000 miles. The inscrutable Sphinx has seen the aeroplanes of to-day pass and re-pass, majestic in the exactness and ease of their flight. Chavez, in one of the most daring flights ever made, crossed over the chasms and snow-covered peaks of the Alps. Exploits, almost as thrilling, have been performed by a score of other aviators; the Pyrenées, the Irish Channel, and the Hudson River, are but a few of the scenes of well-executed achievements, and aeroplanes have been flown under weather conditions that, formerly, would have been considered prohibitive.

Throughout the past year aviators have exhibited consummate skill, as well as a courage that was often foolhardy, in mounting higher and higher, until finally Hoxsey had attained the wonderful altitude of 11,400 feet. The sight of these human birds, hovering beyond the clouds, like Pascal's famous point, "in equilibrium in the infinite," is truly an impressive one.

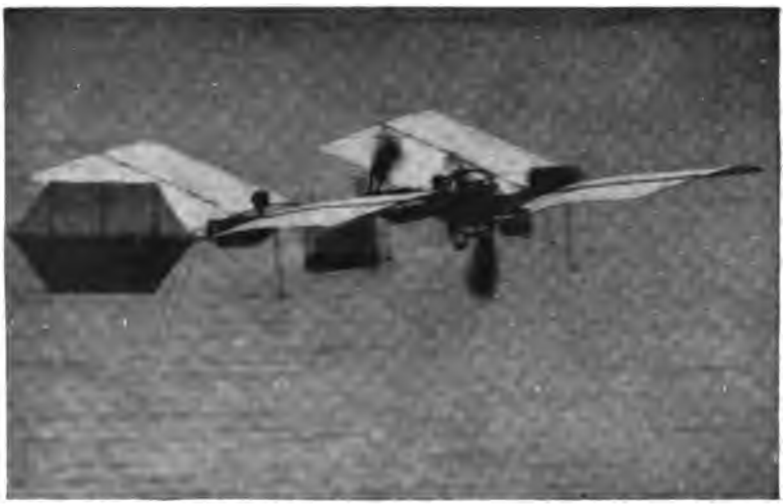
But in the active excitement of the present, the work of the early pioneers must not be lost sight of.

Langley, Lilienthal, and Chanute have contributed so largely and so well to the progress of aviation, that practical aeroplane designers of the present owe them a debt of gratitude that can hardly be repaid.

It is both interesting and appropriate to sum up the work done by these three great pioneers, and point out the effect their labors have had upon the highly successful efforts of the Wrights, Blériot, Levavasseur, and their contemporaries.

LANGLEY

It was in 1887 that Prof. Langley commenced his experiments in aerodynamics, the results of which led him to theoretical conclusions that are fundamental. Largely through the generosity of Mr. William Thaw, of Pittsburg, Prof. Langley was enabled to construct his famous "whirling table" at Allegheny, Pa. With the scientific thoroughness and exactness that had characterized his previous



TELEPHOTO SNAPSHOT OF LANGLEY'S MODEL IN FLIGHT

The two propellers at the rear of the leading planes are seen in rotation, at either side of the motor. At the rear is another set of monoplane surfaces. The cruciform tail piece was practically automatic in its action and kept the machine on a straight course.

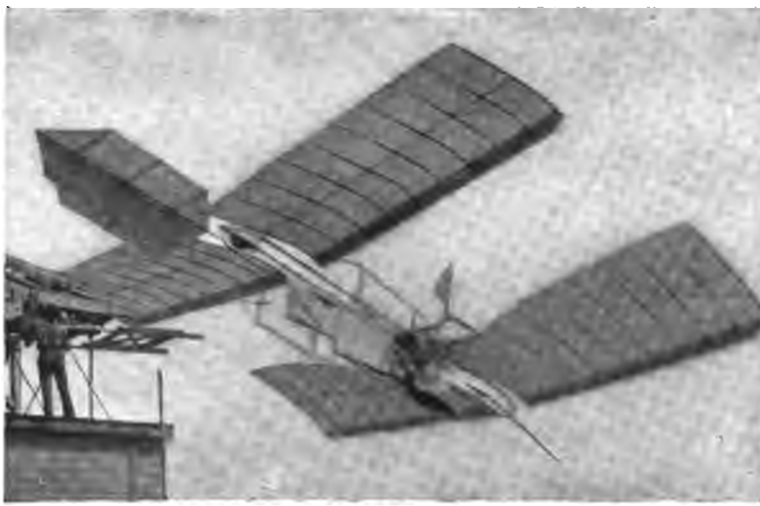
work in physics and astronomy, Langley set vigorously to work to investigate the problem of mechanical flight.

The "whirling table" consisted of a horizontal rotating arm, at the outer end of which were carried the surfaces, forms, and propellers that were to be tested. Almost all the results, of pressure, velocity, etc., were recorded automatically by means of ingenious electrical devices. The actual results of his experiments are referred to in full elsewhere in this work, but it may be pointed out that, unquestionably, his greatest contribution to the knowledge on this subject was his thoroughly scientific verification of the fact, that the old Newtonian theorem on the pressure of air, experienced by a surface inclined at small angles, gave results that were almost twenty times too small. In addition, Langley investigated the well-

SAMUEL PIERPONT LANGLEY

known constant K, and obtained a value nearer the correct one than any of his predecessors. He also determined fully the variation in position of the center of pressure, the analysis of the total pressure on a surface into a lifting force and a resisting one, the effect of "aspect ratio," and other equally important and valuable matters; but inasmuch as these experiments were made on flat surfaces, their results have had little application to the design of the present-day aeroplane. Langley considered the actual friction of the air negligible, and this is the only important characteristic of his work that is open to question.

Langley had an illustrious contemporary in Col. Renard, the builder of the first successful dirigible balloon, the "La France," who experimented exhaustively on planes, propellers and shapes of "least resistance" in his laboratory near Paris, and whose results to-day are of immense value to designers of dirigible balloons. Maxim, Kress, Dines, Phillips, and Hargrave followed Langley, and



FALSE START OF THE LANGLEY MAN-CARRYING "AERODROME" IN 1903
This machine was a faithful copy of the successful model.

contributed handsomely to the progress of aerodynamics, but it is in the character, and especially in the presentation, of his work that Langley stands out as the first and greatest pioneer.

In 1891, after the completion and publication of his "Experiments in Aerodynamics," Langley actively began the construction of flying machines. At first he experimented with models driven by rubber bands, but he found the flights too short and erratic to give any practical results.

His first steam motor-driven "model" aerodrome "No. 0," was then constructed, and was followed by "No. 1" and "No. 2," driven by compressed air and carbonic-acid gas motors. All of these failed because of the poor character of the motors. The next model, "No. 3," was built stronger and was more successful. The propellers were tested in the shop, being attached to a pendulum device. This pendulum, resting on knife edges, was prolonged

THE WRECKED "AERODROME" IN THE POTOMAC RIVER
The motor and some details of the framing are clearly shown here.

above the points of support, and was counterbalanced to give indifferent equilibrium. The propellers were so mounted that the line of thrust passed through the center of gravity, and when power was applied, they lifted the pendulum, thus enabling the dead-lift power of the engines to become known.

The engines of "No. 3" lifted 30 per cent of their own weight. "No. 4" was then built and taken to the Potomac on a house-boat, to be extensively tested. Great difficulties were experienced in launching, and it was found that the upward pressure of the air deflected the wings, this minute difference causing the planes to act badly.

In 1894 and 1895 "No. 5" and "No. 6," stronger and better machines, were constructed.

Finally, on May 6th and November 28th, 1896, Langley's best

TOWING THE WRECKED "AERODROME" BACK TO THE HOUSEBOAT

model, driven by a 1 horse-power steam engine and weighing 27 pounds, was successfully flown several times; the best flight was over *three-quarters of a mile long*, and conclusively demonstrated the saneness and excellence of his work.

The United States government then made an allotment of $50,-000 to Langley for the construction of a man-carrying aerodrome, which was finally completed and tried on October 7th, 1903. This aeroplane, as can be seen from the photographs, consisted of two sets of arched monoplane surfaces, with a central *fuselage* and a controllable cruciform tail very similar to that on the present Breguet biplane (see p. 163). The two propellers rotating in opposite directions were situated back of the front planes, and were driven by a light 50 horse-power steam engine, designed by Mr. C. M. Manley.

The machine would undoubtedly have flown had not an unfortunate breakage in the launching apparatus occurred, just as the aerodrome took to flight, causing it to lose its equilibrium and plunge downward into the water. Mr. Manley, who was on the machine, was rescued unhurt, but the aerodrome was so badly wrecked that no further experiments could be conducted with it. A section of the press then took a hostile attitude, and succeeded in discouraging Congress from any further appropriations. The public in general looked upon this wreck as conclusive evidence of the impracticability of Langley's work, and the brilliant investigator finally died three years later, broken-in heart by the unjust criticisms of his noble efforts.

As aviation progresses, however, the great worth of his work becomes more and more manifest, and few now hesitate to give to him the enormous credit that is his due.

The effect of Langley's labor has been more pronounced on the theory of flight than on actual practice. The general lines of some of the French monoplanes, nevertheless, especially those with large lifting tails, closely resemble his machine, and one of M. Blériot's first successful monoplanes was a "Langley type."

LILIENTHAL

What Langley did to advance the aerodynamics of flat surfaces, Otto Lilienthal did for arched surfaces. But, in addition, this great German pioneer launched himself into the air on wings, and, from his personal experiences, laid down the first great laws of practical flight, as we know it to-day. The work of Lilienthal has without doubt had permanent effect on actual flying, and it is certain that without it we would not have progressed so fast.

The results of his experiments on arched surfaces, obtained by him in conjunction with his brother, after years of quiet scientific study and experiment, were published in 1889 in his monumental work "Der Vogelflug als Grundlage der Fliegekunst."

Lilienthal early recognized the importance of investigating the flight of birds, and the results of his experiments as well as the important discoveries he made are fully treated of later.

OTTO LILIENTHAL

To develop his theories and gain the experience he desired, Lilienthal constructed numerous gliding machines. 80 to 170 square feet in area, in which he launched himself into the face of the wind from the top of a mound of earth at Lichterfeld near Berlin. From a height of over 100 feet he glided down for a distance of 600 to 1,000 feet, landing gently at the bottom of the hill. In all he made over two thousand flights, and was the first man in the world to remain in the air on a heavier-than-air apparatus for any considerable length of time. He flew at first without any motive power, and succeeded in deviating his direction of flight to the right or left merely by altering the position of his center of gravity by a corresponding movement of his legs, which were dangling freely from the seat. Later, as he became more and more expert in the art of keeping his equilibrium, he built and flew a double-deck machine equipped with a 2½ horse-power engine, by the aid of which he could feebly flap the wings, thus greatly extending the lengths of his glides. At this promising stage, August, 1896, an unexpected calamity removed him from

LILIENTHAL IN FREE FLIGHT ON HIS BIPLANE APPARATUS, SHOWING THE CHARACTER OF THE FRAMEWORK AND SHAPE OF THE PLANES, AS WELL AS THE REAR TAIL PIECE

The equilibrium was preserved by the swinging of the legs.

his sphere of work. While testing a horizontal steering arrangement fixed on an old and well-worn machine, he suddenly fell from a height of 50 feet, and broke his spine, a tragic martyrdom which later impressed so forcibly the two ingenious Wright brothers of Dayton, Ohio, that they resolved to follow in his footsteps, and if possible perfect the flying machine. In 1896 Pilcher in England, and Herring in America, built Lilienthal type gliders and flew them successfully.

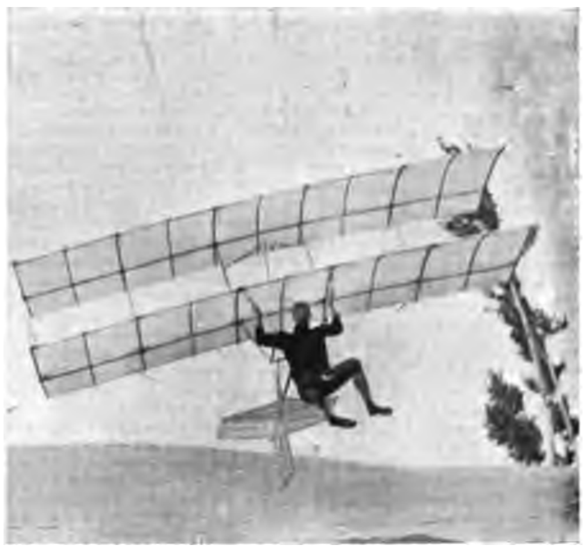
Lilienthal's greatest contribution to the advance of flight was his suggestion and proof of the fact that "as a due preparation for eventual human flight, practice in gliding flight, without the use of a motor, constitutes the best beginning."

CHANUTE

Octave Chanute, who early achieved a remarkable reputation in his profession of civil engineering serving at one time as Chief Engineer of the Erie Railroad, turned his attention to the problem of flight in his later years. In 1894 Chanute contributed to the literature on the subject his interesting work, "Progress in Flying Machines," about the most complete historical treatise on aviation ever written. He concluded from his investigations that equilibrium was the most important problem to solve, and suggested that the simplest way to obtain it was by movement of the surfaces, and not of the man.

Inspired by the example of Lilienthal, he began to experiment in 1896, and the first machine to be tried out on the shores of Lake Michigan was a Lilienthal type, built by his assistant, Mr. A. M. Herring, who had already experimented with two similar machines. After about one hundred glides had been made, the equilibrium was found so precarious and so difficult to control that the machine was pronounced dangerous and discarded. A month later Lilienthal's sad death came to confirm this decision. About the same time a "multiple-winged" machine was tested in about three hundred glides. On this machine the planes could be made to swing to and fro horizontally, thus enabling the position of the center of pressure with respect to the center of gravity to be changed. After a few more experimental machines, the famous Chanute "double-decker" was constructed and successfully tested. This machine was the direct prototype of the present-day biplane, and embodied in its construction for the first time the bridge truss of wood braced by steel wires which is to-day so widely used. Some seven hundred glides were made with this apparatus, and it is of immense importance to point out that not the slightest accident occurred during any of Chanute's experiments.

Before the end of the century Chanute's experiments were



CHANUTE GLIDER STRUCK BY A SIDE GUST; THE BODY SWINGING OVER TO THE RIGHT SIDE (OF THE PHOTOGRAPH) TO RESTORE EQUILIBRIUM

taken up by the Wright brothers, to whom he freely gave his assistance and valuable advice. In the summers of 1900 and 1901 the Wrights proceeded to follow the suggestion of Lilienthal that practice is the key to the secret of flying. and in the numerous glides executed at Kill Devil Hill, North Carolina, they gradually, and with infinite skill, made themselves masters of the air. The early Wright gliders greatly resembled the Chanute machines in construction, but differed in that a movable elevation control was placed in front, and the wings were made warpable for transverse control. The aviator lay prone on the lower plane, thus materially reducing head resistance.

Finally on December 17th, 1903, the first prolonged motor-driven aeroplane flights were made. The machine used at this time

THE HERALD OF A NEW ERA
A Wright aeroplane in flight at dawn.

by the Wrights measured 40 feet in spread, weighed 700 pounds with the operator, and was equipped with three propellers, two at the rear and one below the plane to assist in lifting. The propellers were driven by a four-cylinder 16 horse-power gasoline motor weighing 152 pounds. The speed attained in the four short flights made was about 30 to 35 miles per hour, and the longest time in the air was 59 seconds.

All during 1904 short practice flights were made at Dayton, often resulting in more or less serious breakages. On October 14th, 1904, three flights of over 4,000 feet were made.

BLERIOT DRIVING THE "NO. VIII TER," ON HIS 18-MILE TRIP FROM TOURY TO ARTENAY, FRANCE, OCT. 31, 1908

The movable ailerons and the rudders at the rear are shown in this photograph.

Another machine was built in 1905, embodying several improvements suggested by the practice of preceding years. Finally on October 5th, 1905, the Wright biplane flew a distance of 24 1/5 miles in 38 minutes. The world hesitated to believe that such a thing was possible, and for a long time the Wrights were regarded skeptically by many people. The stimulating effects that Chanute's experiments and help had on the work of the Wrights, as well as the adoption by them of his bridge-truss type of construction, are unmistakable.

About this time, abroad, Archdeacon, Blériot, Pelterie, and Ferber, following also in the steps of Chanute, conducted various

FARMAN IN HIS EARLY VOISIN BIPLANE, MAKING THE FIRST CIRCULAR FLIGHT IN EUROPE, JAN. 13, 1908

gliding experiments. On August 22nd, 1906, Santos Dumont, by the aid of a remarkably light motor designed by Levavasseur, made the first motor flight in Europe. France went characteristically wild with enthusiasm, placing little confidence in the reported exploits of the Wrights. At once the Voisins, with Farman and Delagrange, began the development of their machines, and Louis Blériot, with an admirable audacity and industry, built and smashed monoplane after monoplane until he had evolved the highly successful "Blériot VIII.," the first monoplane in the world to make extended trips.

The astonishing progress in aviation was on, and as it rolls and grows in size like the proverbial ball of snow, we should pause and reflect upon the immense value of the work of Langley, Lilienthal, and Chanute.

CHAPTER II.

The Resistance of the Air and the Pressure on Normal Planes

Although the fact that air has inertia is a familiar one, the important deductions to be drawn therefrom, were not fully recognized until the classic experiments of Langley exhibited them in their true import.

The resistance of the air in its bearing upon aeronautics, and especially in the consideration of the pressure on the surface of an aeroplane, is of fundamental importance.

Many values and methods of determining air resistance have been suggested, but they differ widely from each other. Because of this, designers of aeroplanes experience great difficulty in calculating the probable performance of their machines. A small difference in the value of the "constant of air resistance" may mean an over or under estimation of a certain pressure to the extent of several pounds, which in turn may involve added expense and decreased efficiency.

It is therefore desirable to investigate the present knowledge on the subject, not so much for the purpose of theoretic discussion as to arrive at some definite and conclusive values of the various quantities involved, that will be of use to the engineer.

The resistance of the air is directly proportional to its density. The density of the air varies with (1) temperature, (2) pressure, and (3) its state of equilibrium.

An increase of temperature causes air to expand, and therefore the density diminishes. Roughly, the density of the air varies inversely by 0.36 per cent for a difference of 1 deg. C.

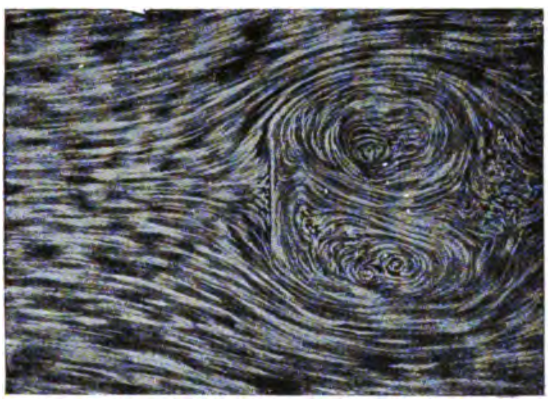
At sea level in our latitudes and at 0 deg. C. 1 cubic foot of air weighs very nearly $1\frac{1}{2}$ ounces if the pressure is at 760 millimeters of mercury. But this pressure decreases as the height above sea level increases. and also at any point is subject to great variations due to meteorological conditions. A difference in pressure of 7.6 millimeters causes a direct variation of the density of about 1 per cent. At 20 deg. C. a difference in height of 340 feet above sea level gives a difference of 10 millimeters in the pressure. At a height of about 18,000 feet, for instance, the density of the air is exactly one-half of that at sea level.

It is only recently that the effect of the condition of equilibrium

AN INSTANTANEOUS PHOTOGRAPH BY PROF. MAREY, SHOWING THE ACTION OF AN AIR STREAM PASSING A NORMAL SURFACE FROM LEFT TO RIGHT

Note the whirls and regions of discontinuity and the compression of the air stream in front of the surface. These marvelous photographs were obtained by admitting thin streams of smoke into the air current.

of the air at any one point upon the density has been considered. The temperature and the pressure in a certain region remaining constant. a gusty wind and several buildings, etc., being in the neighborhood, there would be large variations in the density at different points. The disturbances and eddies set up by normal planes, spheres and spindles, are clearly shown in the accompanying stream line photographs. Even an aeroplane with an arched surface will, if the speed is high enough. leave a region of high density below and in its wake, and a region of low density above and in its wake. Everywhere in the atmosphere, and especially on windy days, there exist "pockets" of high density and of low density, sometimes large enough to completely immerse a full-sized aeroplane. Very often the nature of a country is such that, when the wind comes from a certain direction, a region of low density always forms at some particular point. Abroad at the Rheims aerodrome, and here at our flying grounds at Mineola, such points actually exist, always about in the same place, and are called by the aviators "air holes." An aeroplane entering one of these low-density regions from the air of higher density around it, will suddenly fall without any warning, merely because the pressure has

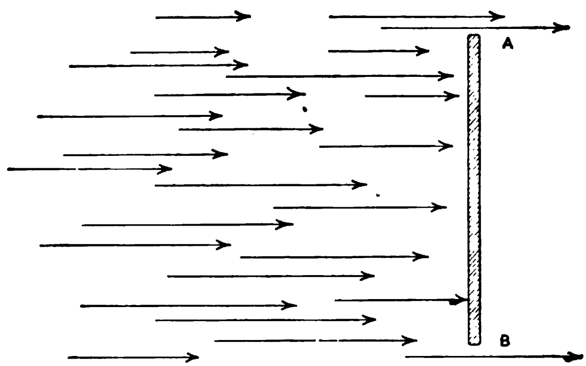


THE ACTION OF A STREAM OF WATER PASSING A NORMAL SURFACE FROM LEFT TO RIGHT. (AHLBORN)

enormously decreased, and the aeroplane has not had time to attain the requisite velocity of support in this lighter medium. Then again, when the machine after this experience passes into the heavier surrounding air, the shock due to the suddenly increased pressure is likely to cause a straining of some part, and a possible breakage. Whenever considering the air in which an aeroplane is flying, we must never lose sight of the fact that this fluid is irregular and unstable in its flow, subject to the most intricate movements and treacherous to the last degree.

The density, therefore, varies greatly, and directly affects the pressures on an aeroplane. In the summer, on a dry clear day, the high temperature causes a low density, and the pressure is light, so that the aeroplane experiences the least resistance, and therefore at this season travels at a higher speed. On the other hand, in winter, with "snow in the air," the density is greatest, thus enabling the aeroplane to carry a much heavier load. Altitude will tend to give a speed increase, and rainy weather an increase of weight-lifting capacity.

Whatever value of air resistance is laid down, consequently, must be taken with reserve, as it is subject to very wide variations.



NEWTON'S IDEA OF THE ACTION OF THE AIR

The particles of air striking directly against a surface placed normal to the air stream, AB representing a section of the surface.

Values of air resistance vary also with the form of the body, and some shapes called "shapes of least resistance," "fusiform," or "stream line form," often experience only half the resistance of an equivalent, flat surface, placed normal to the air current. Only flat normal surfaces are considered here because they give the maximum resistance.

Sir Isaac Newton, in Section VII. Bk. 11, of the Principia, treats "of the motion of fluids, and the resistance made to projected bodies." He defines air as an elastic, non-continued, rare medium, consisting of equal particles freely disposed at equal distances from each other.

Thus if we represent by *A B* the section of a surface against which a stream of air is flowing, then the particles of air, according to Newton, impinge directly against the surface, as indicated by the small arrows in the diagram on p. 20.

In contrast to this Newton defines water, quicksilver, oil, etc., as continued mediums, where all the particles that generate the resistance do not immediately strike against the surface. The surface is pressed on only by the particles that lie next to it, which particles in turn are pressed on by the particles beyond, and so on. The diagram below shows the character of this fluid pressure.

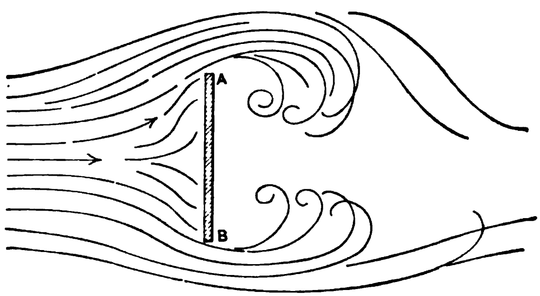


Diagram of the Flow of Air Around a Normal Surface AB

The subsequent experiments of Bernouilli, Euler, Robins, Borda, Bossut, and De Buat showed the imperfection of the first Newtonian theory. That air as a medium is similar in character to water is shown conclusively by the accompanying photographic results of the experiments on stream lines of air by Marey.

The resistance of a "continued" medium of this sort, according to Newton, is in the "duplicate ratio of the velocity" and directly as the density of the medium.[1]

Navier derives a similar relation.[2]

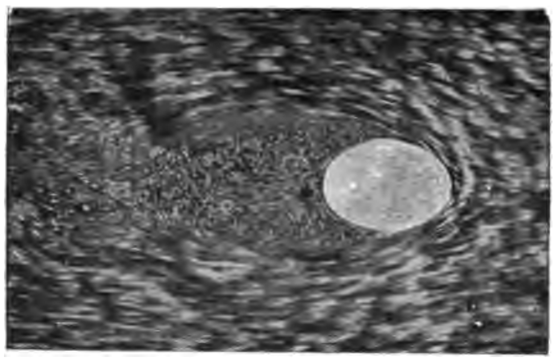
Robins in 1746, with a view to determining the resistance of the air to cannon balls, whirled planes and spheres about a circular orbit, and found that the resistance varied directly as the square of the velocity.

In 1791 Col. Beaufoy carried on a series of experiments, the results of which were published later in connection with the Swedish tests of Lagerhjelm in 1811. and showed also that the pressure varied as the square of the velocity.[3]

Rennie in 1830 abundantly verified this relation for low velocity and it can be accepted as true.[4]

In other words, if we express by P the pressure on a normal surface of area S, generated by an air stream of velocity V, then

$$P=K\ S\ V^2 \qquad (1)$$



THE FLOW OF WATER AROUND AN ELLIPTICAL PRISM FROM RIGHT TO LEFT. (AHLBORN)

where K is a constant of figure involving the density of the air and depending on the barometric pressure, the temperature and the character of the surface and usually termed the "constant of air resistance."

This equation may be derived from the laws of mechanics.

If we let W=the weight of air directed against any normal surface in a given time; w=the weight in pounds of one cubic foot of air; V=the velocity of the air stream in feet per second; S= the area of the surface on which the pressure acts; M=the mass of air of weight W; g=the acceleration due to gravity=32.2 feet per second^2; and P=the pressure on the area S.

Then $W=w\ S\ v$

The momentum of the force on the area $= M\,v = \frac{W v}{g} = \frac{w}{g} S\, v^2$

If S=1 square foot; w=0.0807 pounds per cubic foot for 32 deg. F. and 760 millimeters barometric pressure; and V be expressed in miles per hour, then since P=$M.v$

$P = .0054\ V^2$

K thus taking the theoretical value 0.0054, where V is expressed in miles per hour and P in pounds per square foot. This system of units will be used throughout this discussion.

In 1759 John Smeaton, in discussing some experiments of Rouse, deduced the formula $P = 0.005\ S\ V^2$, and considering S unity he published a table of the velocity and pressure of wind, as given here.[5] The correct Smeaton value for K is 0.00492, but it has become customary in engineering practice to take it as 0.005.

Smeaton adopted this table in his paper on "Mills" from his friend Rouse without any explanation of the kind of experiments from which it had been formed.

Rouse had based his results on a statement by Mariotte, which he verified by his own experiment consisting of whirling a 3 square foot plane in a circular orbit of only 30 feet circumference and at a maximum velocity of 8 miles an hour. Rouse assuming that the resistance varied as the square of the velocity, laid down the law that $P = 0.005.\ V^2$.

SMEATON'S TABLE

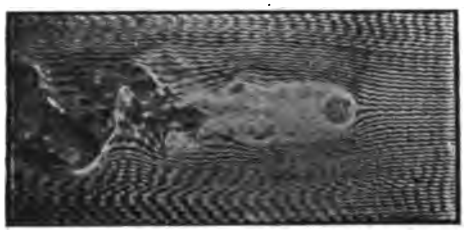
Velocity, Miles per Hour	Pressure, Lbs. per Sq. Ft.	Velocity, Miles per Hour	Pressure, Lbs. per Sq. Ft.
1	.005	40	7.873
2	.020	45	9.963
3	.044	50	12.30
4	.079	55	14.90
5	.123	60	17.71
10	.492	65	20.85
15	1.107	70	24.10
20	1.968	75	27.70
25	3.075	80	31.49
30	4.429	100	49.2
35	6.027		

Smeaton, although misinformed as to the experiments of Mariotte, proceeded to make use of these results and of the constant 0.005 and without any experiments of his own, formulated the well-known Smeaton Table (see p. 23), which appears as standard in the engineering textbooks of all countries.

Bender, in a thorough review of the whole subject, says that Smeaton's table is certainly unreliable.[6]

Hutton in 1787, using a whirling apparatus similar to that used by Robins, deduced the value of K as 0.00426.

The experiments of Didion on falling plates of 11 square feet area in 1837 established K=0.00336, and later experiments by him, the results of which were published in 1848, showed con-



AIR FLOWING FROM RIGHT TO LEFT PAST A CIRCULAR PRISM (MAREY)

This is precisely the character of the disturbance caused by a rod or steel tube on an aeroplane.

clusively that the resistance of the air was directly proportional to the square of the speed.[7]

Col. Duchemin in 1842 conducted experiments on the resistance of fluids which are in many ways remarkable. He investigated the subject very thoroughly and his work is standard. The value of K he derived as 0.00492.[8]

Poncelet, who also did much work in this line, obtained the value of K=0.00275.[9]

Hagen in 1860 obtained the value K=0.00292, and Recknagel in 1886 got the value 0.00287.[10] These experiments were all thorough, and the surfaces were moved in a straight line.

Thibault in 1856 and Goupil in 1884 derived K=0.0053.

Lord Rayleigh also considered the subject theoretically and deduced $K = 0.0055$.[12]

Experiments similar in character to the recent ones of Eiffel were conducted in 1892 by Cailletet and Collardeau and K was found to be 0.0029.[13]

Dr. Pole in 1881 deduced $K=0.0025$, and at some length discussed the absolute unreliability of Smeaton's table.[14]

Langley in his experiments with the rolling carriage in 1888 obtained values of K ranging from 0.00389 to 0.00320.[15]

Col. Renard of the French army, the builder of the famous dirigible "La France," carried out extensive experiments on planes and shapes of "least resistance" in 1887, and deduced the value of $K=0.00348$.[16]

Canovetti in the elaborate experiments conducted by him on inclined railways at Brescia and Brunate in Italy during 1901, determined the value of K as 0.0029.[17]

The most recent and complete experiments on the resistance of the air were conducted by Eiffel in 1903 and 1905. He recognized two sources of inaccuracy—the neglect of the consideration of the separate air filaments which vary at different points on the surface, and the cyclonic motion of the air, due to a revolving source. The experiments were conducted on the Eiffel tower, and the surface was attached to a carriage by springs, the pressure being recorded on a blackened cylinder. The carriage was allowed to fall vertically about 312 feet, and was constrained in its motion by a vertical cable.

The coefficient K varied remarkably little and was practically determined as 0.0031.[18]

Many other values of K have been determined.

Prof. Allen Hazen in 1886 deduced $K=0.0034$.[19]

Dines in 1889 obtained the value 0.0035.[20]

Lilienthal[21] and Von Loessel[22] determined K as 0.13 in metric units or 0.005 in English units.

In 1890 C. F. Marvin at Mount Washington, N. H., where it is said winds as high as 100 miles per hour were observed, got K as 0.004.

T. E. Stanton determined K for small surfaces at 0.0027.[23]

The Voisin brothers, builders of the famous biplane, derived a value of $K=0.0025$.[24]

The Wrights in 1901 conducted experiments on small planes and got the value of K as 0.0033.

Other formulæ than the one now so generally in use (formula I) have been suggested.

Canovetti lays down for unit surfaces the empirical formula: $P=0.0324\ V^2+0.432\ v$ (in metric units) as a result of his experiments.[25]

Experiments conducted by Morin, Piobert, and Didion in France about 1837 indicated that

$$P = 0.0073 + 0.0034\ V^2$$

THE AIR FLOW PAST A CIRCULAR SECTION, UNDER DIFFERENT LIGHT

The bright regions indicate high pressure and the dark regions as at the rear of the section indicate rarefaction.

Soreau in 1902 proposed a formula which for small velocities shows the pressure to vary as the square of the velocity and for higher velocities as the cube.[26]

Renard had previously pointed out that the general formula

$$P=K\ S\ V^2$$

was bad for either very low or very high velocities.[27]

Zahm, in measuring projectile resistances, found the pressure to vary as the cube of the velocity for high speeds.[28]

Eiffel found that between 18 and 40 meters per second the pressure was proportional to the square of the velocity, and at speeds above 33 meters per second it already began to increase and vary as the cube. It is hardly probable, however, that aeroplanes will ever reach velocities where the pressure will vary other than sensibly as the square.

Interesting experiments conducted by A. R. Wolff showed that K for 45 degrees Fahr. was equivalent to Smeaton's value, that at 0 deg. Fahr. it was 10 per cent greater, and at 100 deg. Fahr. 10 per cent less.[29]

Langley, in considering the effect of temperature on density, expresses the relation between pressure and velocity for unit surface in the form,

$$P = \frac{KV^2}{1+0.00366(t-10 \text{ deg.})}$$

where 0.00366 is the coefficient for expansion of air per degree C., t=temperature of the air in degrees C., and K is expressed for 10 deg. C. in metric units.

Prof. Kernot in experiments conducted on the Forth Bridge found the average pressure on large surfaces such as railway coaches, houses, etc., never exceeded two-thirds of that upon a surface of 1 or 2 square feet.[30] The variable density of air puffs, whirls, etc., would account for this, and probably the maximum intensity of pressure is confined to small areas.

Borda, Hutton, and Thibault found from their researches that the resistance increased with the absolute size of surface, while Dines holds a contrary opinion. Von Loessl's experiments showed that small and large surfaces experience resistances simply proportional to their sizes.

Eiffel found that K increased with the surface, but this increase was less and less as the size increased, and tended toward a maximum of 0.0033.

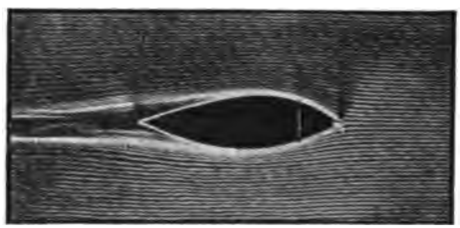
Soreau, after investigating the subject, gives it as his opinion that K may vary slightly with increase of size, but in the necessary approximations that are made in aeroplane design such variation would be negligible.

Most of the experiments cited thus far have been conducted on planes and shapes of very small size, and show large discrepancies.

The method of experimenting by use of a whirling table is unquestionably inaccurate, because the air in the vicinity of the apparatus is itself set in a rotating motion.

Many of these results, therefore, because of the inadequate character of the apparatus used cannot be conclusively applied to the case of an aeroplane in flight.

Those experiments conducted in a straight line, however, more nearly resemble the actual conditions, and it need hardly be pointed out that the character of the air resistance to a fast moving train resembles much more the resistance experienced by a full sized aeroplane in flight, than any other of the methods used.



THE AIR FLOWING BY A STREAM-LINE FORM, SHOWING THE GREATER EVENNESS OF FLOW, AND THEREFORE DECREASE OF RESISTANCE

Numerous and excellent experiments on the resistance to trains have been conducted.

Mr. Scott Russell as early as 1846, in discussing the resistance of the atmosphere to trains, stated that the results of his experiments showed that the pressure according to Smeaton's Table was almost double the actual pressure on a plane and that the formula $P = 0.0025\ S\ V^2$ was correct.[31]

In 1901 J. A. F. Aspinall in experiments on trains carefully measured the air resistance by pressure gages and found $K = 0.003$. In his paper on this subject previous experiments are discussed very thoroughly, and in the fifty-five different formulæ and experiments on the resistance to trains that he cites, the large majority of them make use of values of K below 0.003.[32]

The most recent and accurate results in this line are given by the experiments on air resistance conducted during the tests of the high-speed electric trains on the Berlin Zossen Railway in 1903.[33]

The velocities attained were as high as 110 miles an hour, and the air resistance was carefully measured by an elaborate set of accurate pressure gages.

The results were plotted on a large chart and the mean value of the observations showed that

$$P = 0.0027\ S\ V^2.$$

These experiments are undoubtedly the most accurate and the best applicable to the actual conditions of a large body moving through the air at high speed, that have ever been conducted, and show conclusively that the values of air pressure as originally formulated by Smeaton are very seriously at fault.

There are then to be distinguished two main methods of determining K, one by a rotational apparatus, and the other by movement in a straight line.

In the following tables experiments according to these two systems are separately grouped, and the values given are weighted.

Table of Values of K as Determined by Rotating Apparatus

Name.	Year.	Value.
Rouse	1758	.00500
Hutton	1787	.00426
Duchemin	1842	.00492
Hazen	1886	.00340
Renard	1887	.00348
Langley	1888	.00389
Dines	1889	.00350
Lilienthal	1889	.00500
Marvin	1890	.00400
Loessl	1899	.00530

Mean value. . . . . =0.004275

Mean weighted value. . . . . =0.00421

Table of Values of K as Determined by Straight Line Motion

Name.	Year.	Value.
Didion	1837	.00330
Poncelet	1840	.00275
Russell	1846	.00250
Hagen	1860	.00292
Pole	1881	.00250
Recknagel	1886	.00287
Cailletet	1892	.00290
Canovetti	1901	.00290
Wright	1901	.00330
Aspinall	1901	.00300
Stanton	1903	.00270
Zossen	1903	.00270
Eiffel	1905	.00310
Voisin	1907	.00250

Mean value...............=0.00285
Mean weighted value......=0.00290

according to the completeness of the experiments, the accuracy, the time, whether very old or very recent, and the size of apparatus used. Mean values, and weighted mean values are then obtained. It must be borne in mind that the object of this investigation is to derive a working value of K applicable to full sized aeroplanes, and therefore experiments conducted on large surfaces are weighted more than those on small ones.

Grouping these results three distinct values of K are arrived at:

(1) K=0.0054 (By theory).
(2) K=0.0042 (By rotational apparatus).
(3) K=0.0029 (By movement in a straight line).

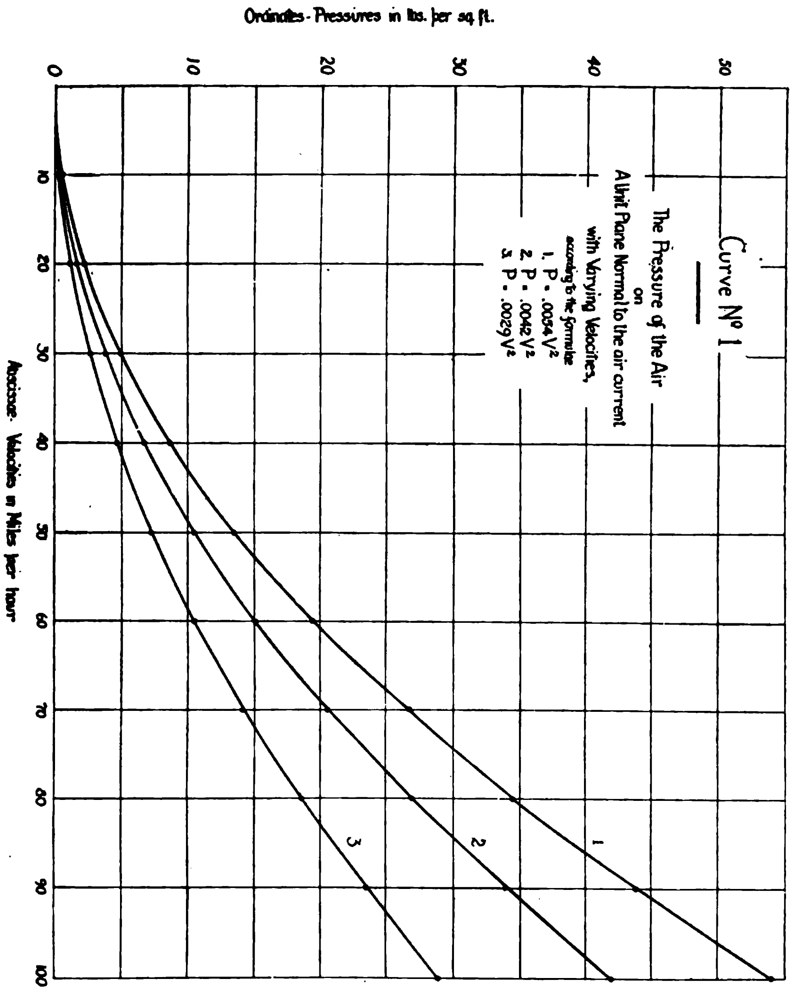
For the purposes of calculations of pressures on an aeroplane value (3) is unquestionably the most correct one.

These results are graphically represented in Curve 1, which shows the great difference in the theoretical value of air resistance and value (3) very strikingly.

We may therefore conclude that for calculations of air pressure as applied to aeroplanes, the most practical expression of such pressure is

$$P_{90} = 0.003\ S\ V^2$$

where $K = 0.003$, and $P_{90} =$ the pressure on a surface of area S, normal to the air stream of velocity V.



An examination of stream-line photographs similar to those reproduced here, reveals distinctly the fact that the air stream directed against a normal surface is deflected at an angle, varying with the conformation of the surface. In the diagram below such a condition of air flow is shown in an exaggerated manner. This suggests a method of obtaining a rational value of *K*, by al-

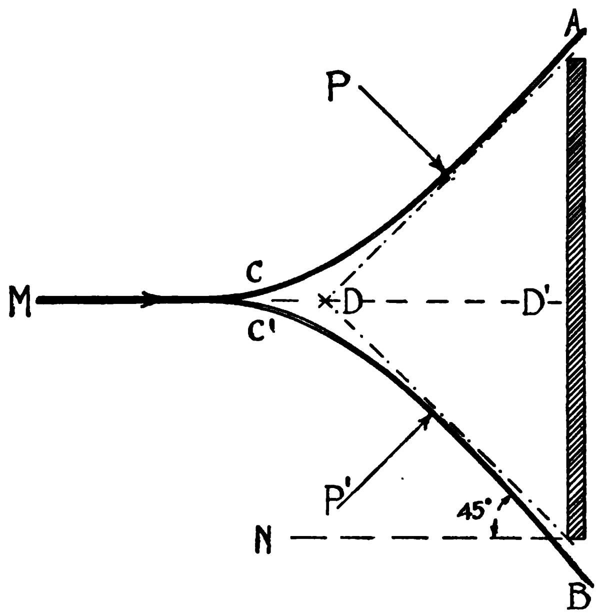


DIAGRAM SHOWING A POSSIBLE ACTION OF STREAMS OF AIR *MCA* AND *MC'B* ON A SURFACE *AB*

most the same process of mechanics as that used in deriving the value 0.0054 if the primary condition there, that the air is deviated at 90 deg. is discarded.

Instead, as we see by the diagram above, the air streams are deviated from their original horizontal direction to a direction *C'B* or *CA*, at an angle *C'BN*, which in many instances of air-flow against a flat normal surface may be as low as 45 deg.

MCA and *MC'B*, the two filets of air when suddenly directed against the surface *AB*, are likely to imprison a cushion of air *ADB*. The air stream presses on this air cushion along *DB* and *DA*, and causes it to transmit the pressure in all directions, as in any fluid. This means that there will be a compression in the air cushion itself along the region *DD'*, as well as a pressure on the surface itself. The moving air stream will therefore cause pressure *P* and *P'* to act normal to *DA* and *DB*, and in addition there will be a resistance due to the internal friction of the fluid along *DA* and *DB*. But in no case do we have a moving mass of air striking a surface at 90 deg. to its line of motion. The fact that the hypothetical surfaces *DA* and *DB* are at an angle of inclination means that the pressure exerted on them will be to the pressure considered previously for the 90 deg. normal condition (0.0054) as the sine of 45 deg. is to the sine of 90 deg., or roughly, as 0.71 to 1. Therefore instead of the theoretical value 0.0054 we would have $0.71 \times 0.0054 = 0.0038$, a value which certainly is much more reasonable.

This method is open undoubtedly to question, but is suggested here as a line of investigation that holds promise of bringing theoretical aerodynamics more easily in accord than any other with the actual results of experiment.

[1] Newton, I., Principia, Prop. XXXVII., Bk. II.
[2] Navier, v. 11, Mem de l'Inst. de France.
[3] Beaufoy, "Nautical Experiments," London, 1834.
[4] Rennie, "On Resist. of Bodies in Air," Tran. Roy. Soc., 1831, p. 423.
[5] Chanute, "Progress in Flying Machines": Rost, F., "Flugapparate"; Kent, p. 492.
[6] Bender, Proc. Inst. Civ. Eng., v. 69, p. 83.
[7] Didion, M., "Traite de Balistique," Paris, 1848.
[8] Duchemin, "Les Lois de la Resistance des Fluides."
[9] Poncelet, "Mecanique Industrielle," p. 601.
[10] Recknagel, "Uber Luftwiderstand," Zeit. Ver. Deut. Ing., 1886.
[11] Goupil, La Locomotion Aerienne, 1884.
[12] Rayleigh, "Resistance of Fluids," Phil. Mag., 1876.
[13] Cailletet and Collardeau, Comptes Rendus, 1892.
[14] Pole, Proc. Inst. Civ. Eng., v. 69, p. 205.
[15] Langley, "Experiments in Aerodynamics," p. 94.
[16] Renard, Ch., "Sur la Resistance de l'Air," Rev. de l'Aeronautique, v. 2, p. 31.

[17] Maleire, E., Genie Civil, v. 51, p. 245; Canovetti, C., Aerophile, v. 10, p. 140; Sci. Am., v. 96, p. 171.

[18] Eiffel, A. G., "Recherches sur la Resistance de l'Air," Paris, 1907; Comptes Rendus, v. 137, p. 30; Aerophile, v. 17, p. 5.

[19] Hazen, A., Am. Jour. Sci., v. 134, p. 241.

[20] Dines, Proc. Roy. Soc., v. 48, p. 252.

[21] Lilienthal, O., "Der Vogelflug, als Grundlage der Fliegekunst." Berlin, 1889.

[22] Ritter v. Loessl, F., "Die Luftwiderstand-gesetze." Vienna, 1895; Zeit. für Luft., v. 10, p. 235.

[23] Stanton, T. E., Proc. Inst. Civ. Eng., v. 156, p. 78.

[24] Voisin, G. and C., "Sur la valuer de K," Rev. de l'Aviation." August 15th, 1907.

[25] Canovetti, C., Paris Acad. Sci., v. 144, p. 1030.

[26] Soreau, R., "Nouvelle loi de la Resistance de l'Air," Soc. des Ing. Civ., p. 464, v. 2, 1902.

[27] Renard, Ch., Sci. Am. Sup., v. 34, p. 13819.

[28] Zahm, A. F., "Resistance of the Air."

[29] Wolff, A. R., "The Windmill as a Prime Mover."

[30] Kernot, Eng. Rec., February 20th, 1894.

[31] Russell, Scott, Proc. Inst. Civ. Eng., v. 5, p. 288.

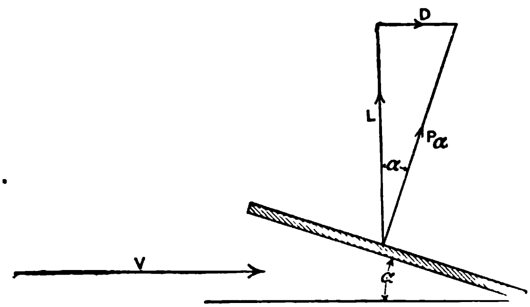
[32] Aspinall, J. A. F., "Train Resistance," Proc. Inst. Civ. Eng., v. 147, p. 155.

[33] Street Railway Journal, v. 19, p. 726.

CHAPTER III.

FLAT INCLINED PLANES

IF a thin flat plane is inclined at an angle a above the horizontal (diagram on this page), and if this plane is then placed in a current of air moving at a velocity V, as indicated by the arrow, the air stream will generate a force P_a in the surface tending to move it in the direction shown on P_a (which direction is always perpendicular to the plane when flat surfaces are used).



THE FORCES ON A FLAT PLANE IN AN AIR CURRENT OF VELOCITY V, AND SET AT AN ANGLE OF INCIDENCE a

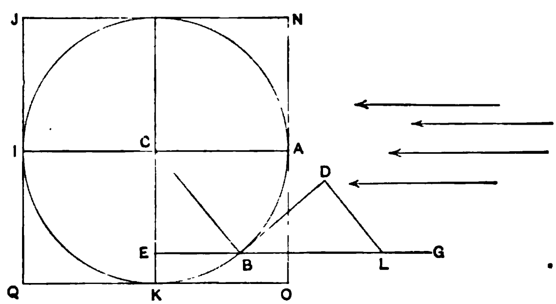
D is overcome by the thrust of the propeller. L, the lift on the planes supports the weight. P is the total effect of the air pressing on the surface as it passes by it.

In Chapter II, the pressure P_{90}, acting on a surface placed normal to the air stream was defined and its value KSV^2 explained. When the plane is inclined, this pressure then called P_a is greatly reduced and varies with the angle of inclination. It is most convenient to express P_a as some part or function of P_{90}. The ratio of P_a/P_{90} then is a numerical quantity, by which P_{90} is multiplied to obtain P_a.

The relation of the pressure of a fluid on an inclined face to that on a normal face was first investigated by Newton in Prop. XXXIV, Bk. II. of his "Principia." and he treats of the subject in the following manner; see diagram on this page.

Let *ABIK* represent a spherical body with center *C*. Let the particles of the medium impinge with a given velocity upon this spherical body in the direction of right lines parallel to *AC*. Let *GB* be one of these right lines.

In *GB* take *LB* equal to *CB* and draw *BD* tangent to sphere at *B*. Upon *KC* and *BD*, let fall the perpendiculars *BE* and *LD*. Then a particle of the medium impinges on the globe at *B* in an



NEWTON'S THEOREM ON THE PRESSURE EXERTED BY AIR AGAINST AN INCLINED SURFACE

oblique direction. Let this force with which it would strike the globe be *F*. A particle of the medium impinges on the face of the cylinder *ONJQ* described about the globe with the axis *ACI*, in a perpendicular direction at *B*. Let this force be F^1.

Then $F : F^1 = LD : LB = BE : BC$.

The force *F* tends to impel the globe in direction *BC*, normal to *BD*. Let this tendency be *T*. And let the tendency of the force to move the globe in direction parallel to *AC* be T^1.

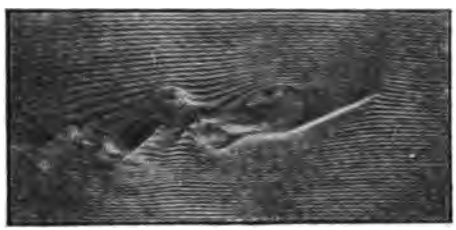
Then $T : T^1 = BE : BC$.

Then joining these ratios if we let P=the pressure exerted on the globe obliquely in the direction *GB* and P^1=the pressure exerted on the face of the cylinder, perpendicularly. in the line *GB*,

$$P : P^1 = BE^2 : BC^2.$$

But *BE* is the sine of the angle *BCE*, and therefore sine of angle *LBD*, which is the angle of incidence of an element of surface to the direction of the wind. We therefore have by the Newtonian theorem, that the pressure of a moving fluid on an inclined surface is proportional to the square of the sine of the angle between the surface and the current.

Navier and Weisbach also advanced this theory with the result that scientists of the highest repute deduced that mechanical flight was practically impossible.



Action of an Air Stream on a Flat Inclined Plane

The angle of incidence is the angle between this plane and the horizontal. The stream is flowing from right to left.

Actual experiment, however, shows that this is absolutely unfounded and that the pressure on an inclined surface varies substantially as the sine of the angle of incidence. The pressure on the inclined surfaces of aeroplanes in use to-day is over 20 times greater than Newton's theorem would indicate, and the difference is more pronounced, the smaller the angle.

The fundamental hypothesis of Newton, that the resistance of the air was due directly to the impact of the particles renders his consideration of this question invalid.

In the excellent stream line photographs of Prof. Marey, reproduced herewith, the character of the air streams about an inclined flat surface are distinctly noticeable, and of themselves refute any suppositon that air acts on such a surface directly by impact. In the detailed study of photographs of stream lines of air, there is no doubt an opportunity of really solving the many problems of aerodynamics, and any number of valuable conclusions can be drawn directly from them. For example, on close examination one is inclined to observe that any form of surface is continually surrounded by a thin film of air, and that the moving air stream never really comes in contact with the surface itself, at all.

In 1763 Borda conducted some experiments on flat inclined surfaces, and proposed a formula in which the pressure was made proportional to the sine of the angle of incidence.

Shortly after this, in 1788, Hutton measured the horizontal component of the pressure on inclined planes by means of a small whirling arm, and these experimental results showed distinctly that Newton's theory was at fault. Hutton deduced the ratio of resistance between inclined and normal planes where α = angle of inclination as $\sin \alpha^{1.842 \cos \alpha}$.

Col. Duchemin in 1842 proposed the formula:[1]

$$P_\alpha = P_{90} \frac{2 \sin \alpha}{1 + \sin^2 \alpha}$$

where P_α is the pressure acting on a plane inclined at angle α with the air current and P_{90} the corresponding pressure on the same plane when placed normal to the current as obtained by the formula:

$$P_{90} = KSV^2 \text{ (see Chapter II)}$$

Hastings proposed the formula:

$$P_\alpha = P_{90}\, 2 \sin \alpha$$

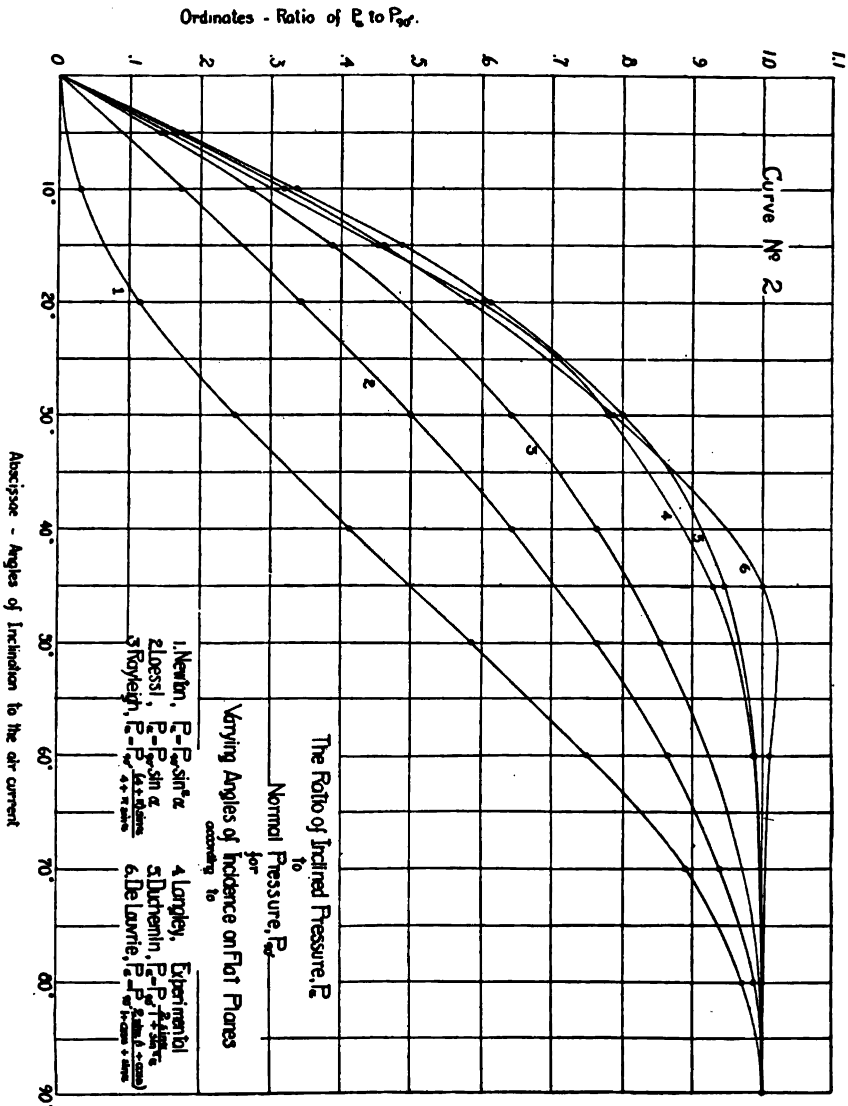
for small angles.

Lord Rayleigh, after investigating this problem[2], expressed the relation between P_{90} and P_α as

$$P_\alpha = P_{90} \times \frac{(4 + \pi) \sin \alpha}{4 + \pi \sin \alpha}$$

This formula was verified by Stanton in 1902.

Combining both theory and experiment in Von Loessl made the


Ordinates - Ratio of P_α to $P_{90°}$.
Curve № 2
The Ratio of Inclined Pressure, P_α to Normal Pressure, P_{90} for Varying Angles of Incidence on Flat Planes according to
1. Newton, $P_\alpha = P_{90} \sin^2 \alpha$
2. Loessl, $P_\alpha = P_{90} \sin \alpha$
3. Rayleigh,
4. Langley, Experimental
5. Duchemin,
6. De Louvrie,
Abscissae - Angles of Inclination to the air current

pressure on an inclined surface directly proportional to the sine of the angle of incidence.[3]

De Louvrie enlarging upon the formula of Duchemin, expressed P_α in terms of P_{90}[4], in the form:

$$P_\alpha = P_{90} \times \frac{2 \sin \alpha (1 + \cos \alpha}{1 + \cos \alpha + \sin \alpha}$$

Dorhandt and Thiesen proposed the formula:

$$P_\alpha = P_{90} \frac{2 \sin \alpha}{1 + \sin \alpha}\left(1 - \frac{0.62 \sin \alpha}{1 + \sin \alpha}\right)$$

Joessel's formula is:

$$P_\alpha = P_{90} \frac{\sin \alpha.}{0.39 + 0.61 \sin \alpha}$$

and Goupil gives

$$P_\alpha = P_{90} (2 \sin \alpha - \sin^2 \alpha)$$

Eiffel, as a result of his earlier experiments (1907), obtained values that led him to adopt the simple formula $P_\alpha = P_{90} \frac{\alpha}{30}$ where $P_\alpha = 1$, when $\alpha = 30$ deg.

Luyties also suggests the formula:

$$P_\alpha = P_{90} (2 \sin \alpha - \sin^2 \alpha.)$$

which gives results almost identical with that of De Louvrie.[5] He further gives the convenient and accurate enough relation for very small angles, proposed by Eiffel.

A formula of substantially the same form as Hutton's was suggested by Soreau quite recently.[6]

Six of these various formulæ are graphically represented in Curve 2, the difference between the Newtonian formula and the others being quite marked.

This curve can be used precisely as a table. If, for example, we desire to determine the pressure on a flat plane, the area of which, $S = 10$ square feet, moving at $V = 30$ miles per hour, and inclined at an angle $\alpha = 20$ deg., the pressure P_{90} is first computed.

$$P_{90} = 0.003 \times S \times V^2$$
$$= 0.003 \times 10 \times 900$$
$$= 27 \text{ pounds.}$$

From the curve we see that a reasonable value for P_{α}/P_{90} when $\alpha = 20$ deg., is about 0.6. Then:

$$P_{\alpha} = 0.6\ P_{90}$$
$$= 0.6 \times 27$$
$$= 16.2 \text{ pounds:}$$

This is the total force acting on this surface under the assumed conditions.

Langley's experiments showed conclusively that the sine squared law was wrong. In the experiments with the resultant pressure recorder,[7] his results show a remarkably close agreement with the formula of Duchemin, as is shown by the accompanying Table. This practically identifies Duchèmin's formula as correct for flat surfaces.

TABLE OF VALUES FOR

Ratio of $\frac{P_{\alpha}}{P_{90}}$, according to Langley and Duchemin

Angle of Inclination.	By Langley's Experiments.	By Duchemin's Formula.
5	.15	.17
10	.30	.34
15	.46	.48
20	.60	.61
25	.71	.72
30	.78	.80
35	.84	.86
40	.89	.91
45	.93	.94

We can therefore conclude for flat surfaces that

$$P_{\alpha} = P_{90} \frac{2 \sin \alpha}{1 + \sin^2 \alpha}$$

where $P_{90} = .003\ SV^2$.

LIFT AND DRIFT

If we represent by P_a (see diagram on p. 35) the pressure acting perpendicular to the surface of a flat plane, inclined at an angle α in a wind current of velocity V, we may resolve it into two components at right angles, one acting perpendicularly and equal to L, and another acting horizontally and equal to D.

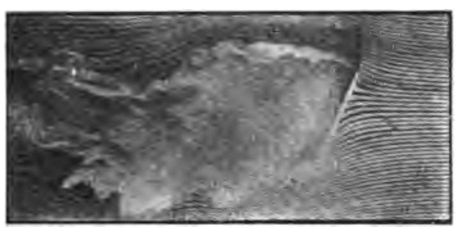
Then $D = P_a \sin \alpha$

and $L = P_a \cos \alpha$

This resolution was indicated by Sir George Cayley as early as 1809.

It is not purely theoretical, however, but has been verified by Langley's experiments as well as by actual practice.

In the present terminology of Aerodynamics we call L the "lift"



A Flat Plane at a High Angle of Incidence Impeding the Air Flow from Right to Left

and D the "drift" of a plane, L being the effective supporting force equal to the weight carried and D the dynamic resistance overcome by the thrust of the propeller.

The velocity of the aeroplane is directly dependent on the value of D, and as D decreases, the resistance to motion becomes less and consequently either the power necessary decreases, or a higher velocity can be obtained.

The ratio of these two quantities L/D, called the ratio of lift to drift, is obviously an excellent means of expressing the aerodynamic efficiency of an aerofoil, and is used as such.

Since one of the primary considerations in aeroplane design is to carry the greatest amount of weight at the highest velocity, or conversely with the least expenditure of power, it is desirable to obtain as high a value for the lift L and as low a value for the drift D, as possible. In other words, we try to obtain a high value of L/D, the ratio of lift to drift.

In gliding flight, the higher the value of L/D, the longer will be the glide.

[1] Duchemin, "Les Lois de la Resistance des Fluides," Paris, 1842.

[2] Rayleigh, Lord, Manch. Philos. Soc., 1900; Nature, v. 27, p. 534; Smith. Inst. Rep., 1900.

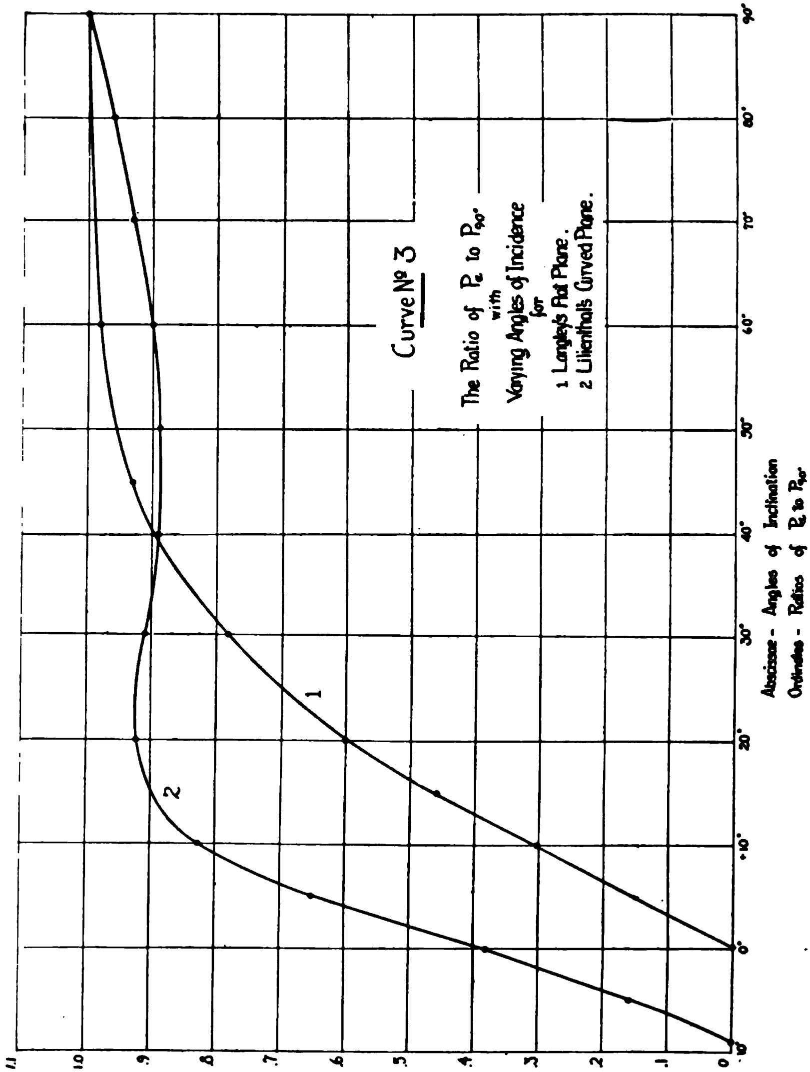
[3] Ritter von Loessl, "Die Luftwiderstandgesetze."

[4] De Louvrie, Ch., Proc. Int. Conference, 1893.

[5] Luyties, O. G., Aeronautics, v. 1, p. 13, No. 3.

[6] Soreau, R., "Nouvelle Formule," Aerophile, v. 17, p. 315.

[7] Langley, "Experiments in Aerodynamics," p. 24.


Curve No 3
The Ratio of P_a to $P_{90°}$
with
Varying Angles of Incidence
for
1 Langley's Flat Plane.
2 Lilienthal's Curved Plane.
1
2
Abscissae - Angles of Inclination
Ordinates - Ratios of P_a to $P_{90°}$
-10° 0° 10° 20° 30° 40° 50° 60° 70° 80° 90°
0 .1 .2 .3 .4 .5 .6 .7 .8 .9 1.0 1.1

CHAPTER IV.

THE PRESSURE ON CURVED PLANES

THE photographs of the stream lines about a curved surface set at a low angle of inclination to the line of flight bear full confirmation of its greater efficiency. In the photograph below is shown the condition of the air flow for an arched or curved plane, almost normal to the air stream, and the regions of low density, high density, and discontinuity appear similar to those for a flat plane. But when this curved plane is inclined only slightly above the horizontal as shown in the photographs on p. 48 and p. 51, the smooth-

AT HIGH ANGLES OF INCIDENCE A CURVED PLANE CAUSES AS GREAT A DISTURBANCE AS A FLAT ONE

ness of flow of the air stream past the surface becomes strikingly evident.

Langley it is said investigated curved surfaces, but his results have not as yet been published.

Lilienthal, striving to imitate the birds, examined carefully the shape and structure of wings of the various species.[1] He recognized the importance of the shape of wing and found after experiment that even very slight curvatures of the wing profile (in section) considerably increased the lifting power.

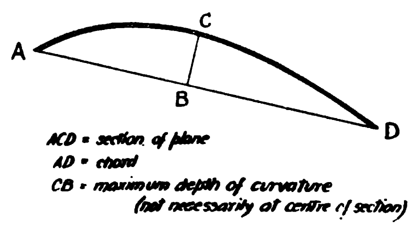
The arching of a surface is the same as its depth of curvature and is also sometimes expressed as its camber or cambered depth.

In the diagram below, if CB is 1/12 of the chord AD, then the surface shown in section has a depth of curvature of 1/12 chord.

In a flat plane the pressure is always perpendicular to the surface and as pointed out above, the ratio of lift to drift is therefore as the cosine to the sine of the angle of incidence.

But in curved surfaces a very different condition exists. The pressure is not uniformly normal to the chord of the arc, but is considerably inclined in front of the perpendicular at low angles with the result that the lift is increased and the drift is decreased.

Lilienthal was the first to discover this significant fact and fully set it forth. He says: "When a wing with an arched profile is



THE SECTION, CHORD, AND DEPTH OF CURVATURE OF A PLANE

"Depth of a plane" is the same as chord.

struck by the wind at an angle a with a velocity V, there will be generated an air pressure P which is not normal to the chord, but is the resultant of a force N, normal to the chord and of another force T, tangential to the chord."

These forces are shown in the diagram on p. 47. The air pressure P_a is precisely analogous to P_a for flat surfaces, in that it represents the total effective force of the air stream on the surface.

To determine N and T, Lilienthal conducted a series of experiments on planes shaped in plan somewhat like a bird's wing (not rectangular). He expressed N and T for the surface he used, 1/12 depth of curvature, as functions of P_{90}.

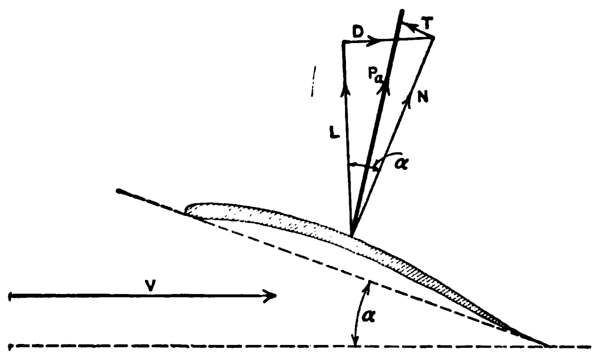
Thus $N = n \times P_{90} = n \times 0.003\ SV^2$

$T = t \times P_{90} = t \times 0.003\ SV^2$

where n and t are numerical quantites; $n = 1$, when $\alpha = 90$ deg. Lilienthal's results are given in the table on p. 49.

Values of n and t show that arched surfaces still possess supporting powers when the angle of incidence becomes negative. The air pressure T becomes a propelling one at angles exceeding 3 deg. up to 30 deg.

As Mr. Chanute pointed out, this does not mean that there is no horizontal component or "drift" of the normal pressure N,



THE FORCES ON A CURVED SURFACE, IN AN AIR STREAM V AT AN ANGLE OF INCIDENCE α

The forces are assumed to be acting through the center of pressure.

under these conditions, but that at certain angles the tangential pressure T, which would be parallel to the surface and only produce friction in the case of a flat plane, acts on a curved surface as a propelling force[2].

Thus if it was desired to find N and T for a surface 100 feet square, moving at 40 miles an hour and set at an angle of incidence of + 6 deg., the normal pressure P_{90} would first be computed.

$$P_{90} = KSV^2 = 0.003 \times 100 \times 1600$$
$$= 480 \text{ pounds.}$$

Then referring to Table (p. 49) we find that at + 6 deg. $n = 0.696$ and $t = -0.021$.

Therefore $N = 0.696 \times 480 = 334$ pounds
and $T = -0.021 \times 480 = -10.1$ pounds.

Since its sign is negative T is a propelling force.

The force N is itself resolved into the components L and D as was done with P_a for a flat plane (see diagram p. 47).

It is to be observed, however, that T is inclined at an angle α above the horizontal. Therefore to obtain its effect as lift and

THE JUSTIFICATION FOR THE USE OF CURVED SURFACES

The air streaming from right to left past a curved plane, showing the great ease of flow. Compare with the action on a flat surface.

drift, it must be resolved into its vertical and horizontal components. These are

$$l = T \sin. \alpha$$
$$d = \pm T \cos. \alpha$$

The force l is almost negligible.

The total effective lift is then:

$$L' = L + l = (N \cos. \alpha) + (T \sin. \alpha)$$

and the total effective drift is:

$$D' = D \pm d = (N \sin \alpha) \pm (T \cos \alpha)$$

To complete the numerical example, sin 6 deg. = 0.105 and cos 6 deg. = 0.995.

Then $L' = (0.995 \times 334) + (0.105 \times 10.1) = 333.5$ pounds
$D' = (0.105 \times 334) - (0.995 \times 10.1) = 25.0$ pounds

In this manner we get the Lift and Drift of the assumed plane at a velocity of 40 miles an hour, according to the Lilienthal method. The ratio of lift to drift for this plane is 13.3.

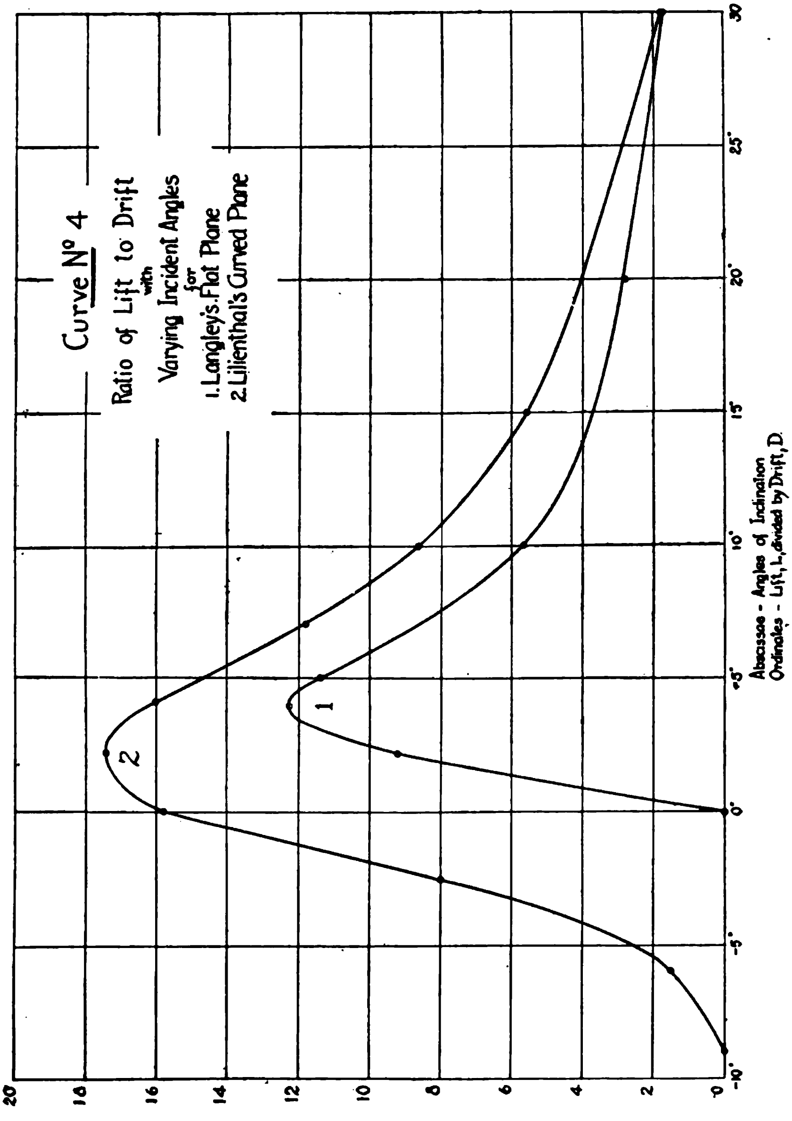
The experiments of Wilbur and Orville Wright at Kitty Hawk verified the existence of "Lilienthal's Tangential," and experiments conducted by them later in the laboratory further supported this fact, although their results were smaller than those of Lilienthal at angles below 10 deg.[3]

LILIENTHAL'S TABLE, 1/12 CURVE

α deg.	n	t	α deg.	n	t
— 9	.000	+.070	16	.909	—.075
— 8	.040	+.067	17	.915	—.073
— 7	.080	+.064	18	.919	—.070
— 6	.120	+.060	19	.921	—.065
— 5	.160	+.055	20	.922	—.059
— 4	.200	+.049	21	.923	—.053
— 3	.242	+.043	22	.924	—.047
— 2	.286	+.037	23	.924	—.041
— 1	.332	+.031	24	.923	—.036
0	.381	+.024	25	.922	—.031
+ 1	.434	+.016	26	.920	—.026
+ 2	.489	+.008	27	.918	—.021
+ 3	.546	.000	28	.915	—.016
+ 4	.600	—.007	29	.912	—.012
+ 5	.650	—.014	30	.910	—.008
+ 6	.696	—.021	32	.906	.000
+ 7	.737	—.028	35	.896	+.010
+ 8	.771	—.035	40	.898	+.016
+ 9	.800	—.042	45	.888	+.020
+10	.825	—.050	50	.888	+.023
11	.846	—.058	55	.890	+.026
12	.864	—.064	60	.900	+.028
13	.879	—.070	70	.930	+.030
14	.891	—.074	80	.960	+.015
15	.901	—.076	90	1.000	.000

Curve 3 shows the variation of the normal pressure on an inclined plane according to Lilienthal (curved), and the same for a flat plane according to Langley. The difference especially for small angles, exhibits at once the greater lifting effect of curved surfaces.

In his experiments, it appears that Lilienthal did not realize


Curve No 4
Ratio of Lift to Drift
with
Varying Incident Angles
for
1. Langley's Flat Plane
2. Lilienthal's Curved Plane
1
2
Abscissae - Angles of Inclination
Ordinates - Lift, L, divided by Drift, D
-10° -5° 0° 5° 10° 15° 20° 25° 30
0 2 4 6 8 10 12 14 16 18 20

the full significance of the movement of the center of pressure or point of application of P_a, away from the center of surface (see p. 64). Accordingly his experimental values of n and t for low angles are far too great. For example, the Wrights, in an experiment conducted by them on a full-sized aeroplane, found that Lilienthal's estimate of the pressure on a curved surface having an angle of incidence of 3 deg. as equal to 0.546 of P_{90} was nearly 50 per cent too great.

Though many excellent treatises have been written on the subject, it is hardly possible with the present knowledge of aerodynamics to explain exactly what the significance of these pressures

THE CONDITION OF THE AIR STREAM FLOWING BY A CURVED PLANE

The dark region above the plane indicates rarefaction.

N and T are, or to bring them under any well-known set of physical laws.

Wegner von Dallwitz, however, has succeeded in arriving at a mathematical expression of the lift of a curved plane as

$$L = K \cos \alpha \tan^2 \alpha \, S.V^2$$

where K is a constant equal to 0.26 when metric units are employed.

The well-known theory of Soreau, in which a number of other constants than K are used, also gives fairly good results by analytical methods.

THE RATIO OF LIFT TO DRIFT

The ratio of Lift to Drift is, as we have seen, of great importance in the design of aeroplanes, and that surface which has the greatest ratio of lift to drift, under working conditions, will be the most efficient from an aerodynamic standpoint, i. e., it carries the greatest weight with the least power.

Curve 4 shows the variation of this ratio with the incident angle for both Langley's flat plane and Lilienthal's arched one.

The difference is very pronounced, and the large values of the ratio for small angles show arched surfaces to be the most economical in flight, especially for soaring or gliding.

Curve 5 shows the variation of the ratio of lift to drift for various shaped surfaces experimented with by A. Rateau in Paris.[4] These experiments were carried on in a very complete manner, and their results are of great practical importance.

These experiments on the relation of sustaining power to head resistance, on various shaped planes, show that a thick curved plane is by far the most stable but not so very efficient. The Antoinette monoplane is equipped with surfaces of this kind.

That a high aspect ratio is of great consequence is shown very clearly by a comparison of the curves corresponding to types 2 and 3.

The variations of the ratio of L/D with aspect ratio and depth of curvature, however, are taken up in detail in Chapter VII; especial reference is made there to the experiments of Prof. Prandtl of Göttingen and M. Eiffel.

Rateau's values of L/D for his curved surface marked No. 3 (see Curve No. 5) are very high, compared to the Prandtl results (see curves Nos. 12, 13, 14).

The 1910 experiments of M. Eiffel on curved surfaces gave very interesting results.[5] In the table on p. 54 some of his values for a curved surface, 150 millimeters $\times$ 900 millimeters, and with a depth of curvature of 2/27 chord, are tabulated in both metric and English units.

M. Eiffel expresses drift as a constant Kx multiplied by SV^2, the usual value of K for P_{90} being included in the values for Kx. The same is done for lift. Obviously at 90 deg., the value of Kx equals the value of K, 00314 (see Chapter II).

Eiffel's values for lift are very high compared to those of Prandtl.

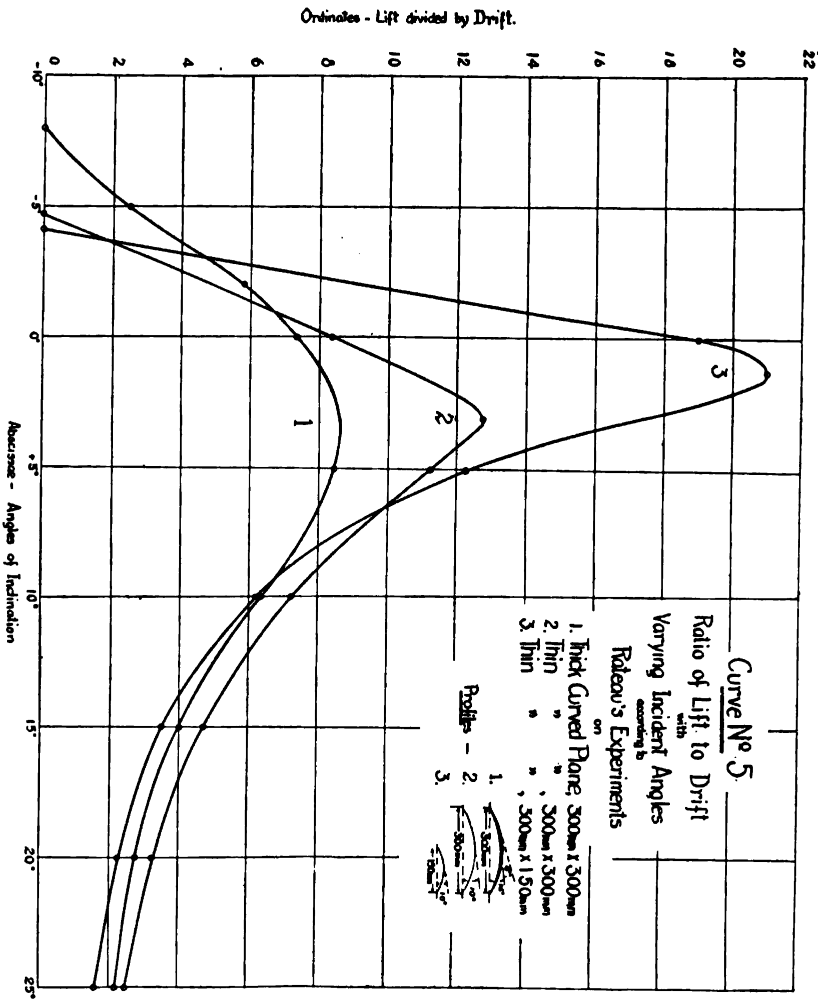

Ordinates - Lift divided by Drift.
Abscissae - Angles of Inclination
Curve No. 5
Ratio of Lift to Drift
with
Varying Incident Angles
according to
Rateau's Experiments
on
1. Thick Curved Plane, 300mm x 300mm
2. Thin " " , 300mm x 300mm
3. Thin " " , 300mm x 150mm
Profiles - 1. 2. 3.

TABLE OF LIFT AND DRIFT OF EIFFEL'S CURVED PLANE

Kx = Drift coef., Ky = Lift coef.

	In Metric Measures.		In English Measures.	
α	Kx	Ky	Kx	Ky
0°	.003	.033	.00012	.00137
5°	.006	.054	.00025	.00224
10°	.009	.072	.00037	.00298
15°	.017	.076	.00071	.00314
20°	.025	.067	.00104	.00278
30°	.034	.062	.00141	.00257
45°	.049	.051	.00203	.00212
60°	.063	.037	.00266	.00153
75°	.073	.020	.00303	.00083
90°	.076	....	.00314	......

Roughly K in metric measures $\div$ by 24.1 = K in English measures.

As an example of the manner in which M. Eiffel's results are used, the same plane already employed to illustrate the Lilienthal method is used again, $S = 100$ square feet, and $V = 40$ miles an hour.

Hence $S.V^2 = 160{,}000$.

Referring to the Table on this page, it is seen that at 6 deg. the lift and drift coefficients are approximately 0.0024 and 0.00028, respectively.

Therefore,

$$\text{Lift} = Ky \times SV^2 = 0.0024 \times 160{,}000 = 384.0 \text{ pounds}$$

$$\text{Drift} = Kx \times SV^2 = 0.00028 \times 160{,}000 = 44.8 \text{ pounds}$$

values that are considerably higher than those of Lilienthal.

[1] Lilienthal, O., "Vogelflug als Grundlage der Fliegekunst" Zeit. für Luft., v. 14, heft 10: Aeron. Annual, No. 3, p. 95.

[2] Chanute, O., "Sailing Flight," Aeron. Annual, No. 3 p. 115.

[3] Wright, W., "Some Aeronautical Experiments," Smith. Inst. Rep. for 1902, p. 145.

[4] Rateau "Recherches Dynamiques," Aerophile, v. 17, p. 338.

[5] Eiffel, G., Soc. des Ing. Civ. de France, 1910; L'Aerophile, Feb. 1, 1910, p. 63.

CHAPTER V.

THE FRICTIONAL RESISTANCE OF AIR

It is well known, from the investigations of Froude and others, that the frictional resistance of a body in water was great. By analogy it would seem as if the friction of the air would also be considerable. Many prominent experimenters and investigators, however, have stated that the tangential resistance of air is negligible.

Langley implicitly assumed the effect of friction at the speeds he used, to be negligible, and did not investigate the problem to any extent.[1]

Clerk Maxwell conducted experiments on the viscosity of the air, i. e., the internal friction of the fluid, and gave the coefficient of viscosity of air as $\mu = 0.0001878\ (1 + 0.0027\ \theta)$, θ and μ being taken as defined in his paper.[2] By this formula the actual tangential force on a plane of one square foot area moving horizontally at 100 feet per second is less than 1/50 of 1 per cent of the pressure on the same plane when moved normally at this speed.

Maxim, Dines, and Kress considered the friction negligible throughout their experiments.[3]

Armengaud and Lanchester, who have thoroughly investigated the subject, take the opposite view and consider skin friction a very appreciable factor in the resistance of an aeroplane.[4]

Lanchester gives the total friction on both ends of a plane as 0.015 of the normal pressure. Thus the frictional resistance F of a flat plane 200 square feet in area, moving at 50 miles an hour, and set at an angle of 20 deg., would be

$$F = 0.015\ (0.003 \times 200 \times 2500) \times (0.59)$$
$$= 13.27 \text{ pounds}$$

In 1882 Dr. Pole investigated the skin frictional resistance of the dirigible balloon of M. Dupuy de Lome and found it to be $0.0000477\ dlv^2$ where d is the diameter, l the length, and v the velocity.[5] This gave a very appreciable value to the frictional resistance.

W. Odell in 1903 conducted experiments for the purpose of determining the friction of the air on rotating parts of machines and arrived at the conclusion that the energy dissipated per second $= c\ w^3\ v^5$ where c is a constant, w the angular velocity of the disks with which he experimented, and v the radius of the disk.[6] The friction was found to be considerable, although the character of his experiments precludes their being applied directly to aeroplanes.

Canovetti found the skin friction on surfaces equal to a constant times the square of the velocity, the constant taking the value 0.00012 when the metric system of units was employed.[7]

The most thorough experiments in this line were conducted by Prof. Zahm in 1903.[8] The results of his experiments showed conclusively that the friction of the air on surfaces was a very considerable factor, and he expressed its general value in the formula:

$$f = 0.0000158\ l^{0.07}\ v^{1.85}$$

where $f =$ the frictional drag in pounds per square foot, $l =$ the length of the surface in the direction of motion in feet, and $v =$ the velocity of the air past the surface in miles per hour.

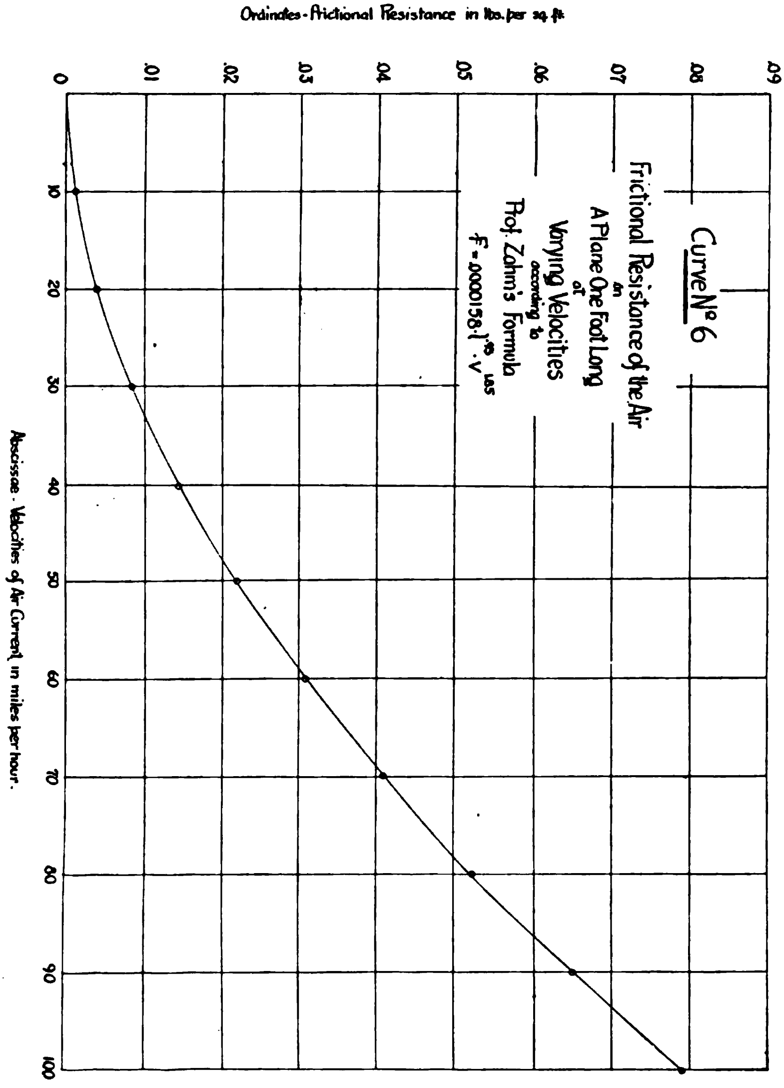
The friction was found approximately the same for all smooth surfaces, but 10 to 15 per cent greater with extremely rough surfaces such as coarse buckram.

The table on page 58 gives Zahm's values for f as obtained by experiment and from the above formula. The frictional drag for any intermediate velocity or length of surface may readily be found by interpolation.

The frictional resistance of a flat or arched aeroplane surface of area S is $$F = 2 \times f \times S$$
the factor 2 being introduced because the value of f refers to a single surface of a plane, while a plane in free flight has, of course, two sides exposed to frictional resistance.

To illustrate the practical application of these results on air friction, the actual frictional resistance F of a biplane consisting of two surfaces, 30 feet wide and 4 feet deep, moving at 60 miles an hour is computed, $S = 240$ square feet. From the table on page 58 the value of $f = 0.0279$.

$$\therefore F = 2 \times 0.0279 \times 240$$
$$= 13.4 \text{ pounds.}$$


Ordinates - Frictional Resistance in lbs. per sq. ft.
Curve No 6
Frictional Resistance of the Air
on
A Plane One Foot Long
at
Varying Velocities
according to
Prof. Zahm's Formula
F = .0000158 · l^.93 · V^1.85
0
.01
.02
.03
.04
.05
.06
.07
.08
.09
10
20
30
40
50
60
70
80
90
100
Abscissae - Velocities of Air Current, in miles per hour.

Wind speed.	Average friction in pounds per square foot.			
	1′ plane.	2′ plane.	4′ plane.	8′ plane.
mi. hr.				
5	0.000303	0.000289	0.000275	0.000262
10	0.00112	0.00105	0 00101	0.000967
15	0.00237	0.00226	0 00215	0.00205
20	0.00402	0.00384	0.00365	0.00349
25	0.00606	0.00579	0.00551	0 00527
30	0.00850	0.00810	0.00772	0.00736
35	0.01130	0.0108	0.0103	0.0098
40	0.0145	0.0138	0.0132	0.0125
50	0.0219	0.0209	0.0199	0.0190
60	0.0307	0.0293	0.0279	0.0265
70	0.0407	0.0390	0.0370	0.0353
80	0.0522	0.0500	0.0474	0.0452
90	0.0650	0.0621	0.0590	0.0563
100	0.0792	0.0755	0.0719	0.0685

SKIN FRICTION TABLE (ZAHM)

This value is very much less than what would be obtained by using Lanchester's method.

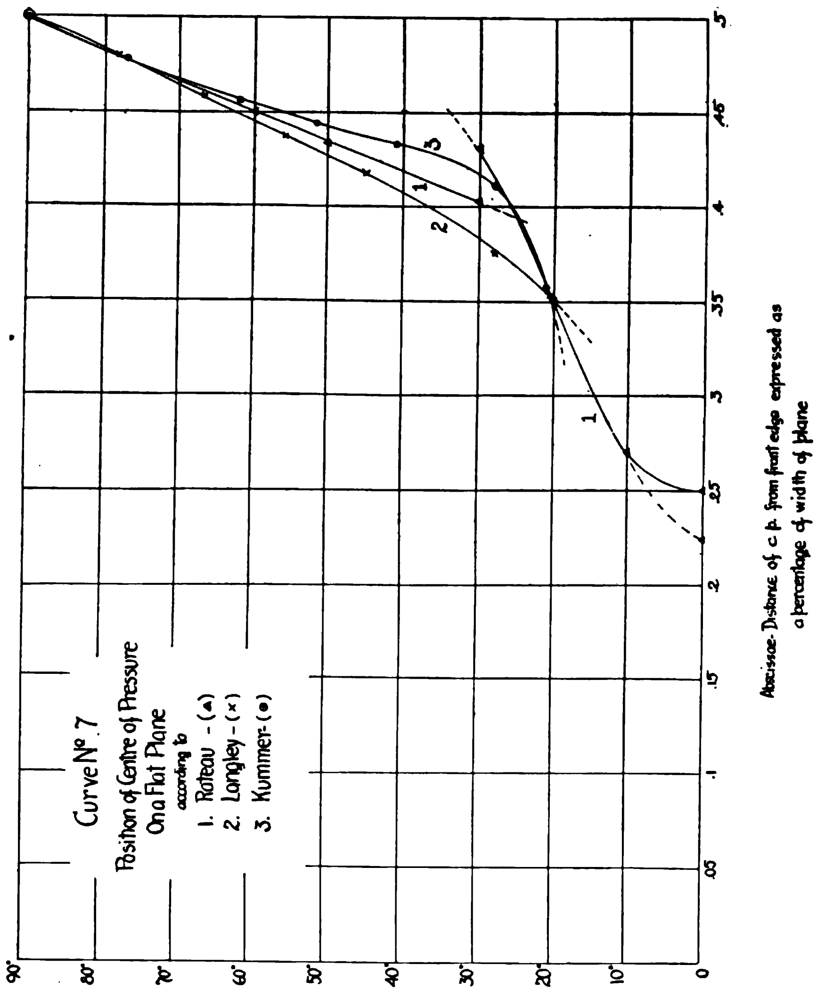
The frictional resistance of air as determined by Zahm bears a striking resemblance to that of water as determined by Froude.[9] Froude found the friction to vary very nearly as $v^{1.85}$, and a comparison of the results indicates that the resistances are proportional in some way to the densities of the two media.

If it is true that the air stream never touches an aeroplane surface but only comes in contact with the air film surrounding it, then the frictional resistance would be the same for all reasonably smooth surfaces, but would be higher for surfaces so rough that the fibers themselves cause regions of discontinuity. This appears to be borne out in the results of the experiments of Prof. Zahm.

Curve 6 shows the variation of the skin friction on a unit surface with speed as plotted from Prof. Zahm's tables.

It is now generally accepted that skin friction is an appreciable factor in the resistance of an aeroplane, and amounts in an average sized machine to from 10 to 25 pounds.

[1] Langley, S. P., "Exp. in Aerodynamics," p. 9.
[2] Maxwell, Clerk, Phil. Trans., v. 157.
[3] Bader.-Powell, Aeronautics (Brit.), v. 1, p. 117.
[4] Lanchester, F. W., "Aerodynamics"; Armengaud, "Probleme de l'Aviation."
[5] Pole, William, Ecl. Eng. Mag., v. 27, p. 1, 1882.
[6] Odell, W., "Experiments on Air Friction," Engineering (London), January, 1904.
[7] Canovetti, "Sur la Resistance de l'Air," Paris, Acad. Sci., v. 144, p. 1030.
[8] Zahm, A. F., "Atmospheric Friction," Bulletin, Phil. Soc. of Wash., v. 14, p. 247.
[9] Froude, Brit. Assoc. Report, 1872.


Curve No. 7
Position of Centre of Pressure
On a Flat Plane
according to
1. Rateau - (▲)
2. Langley - (×)
3. Kummer - (●)
Abscissae - Distance of c p. from front edge expressed as
a percentage of width of plane
90° 80° 70° 60° 50° 40° 30° 20° 10° 0
.05 .1 .15 .2 .25 .3 .35 .4 .45 .5
1
2
3

CHAPTER VI.

THE CENTER OF PRESSURE ON FLAT AND CURVED PLANES

In unsteady winds the center of pressure on an aeroplane moves about greatly, and tends, by its variation in position, to upset the equilibrium, so that the efforts of many experimenters, noticeably Alexander Graham Bell, have been directed to the construction of an aeroplane in which the movement of the center of pressure is made very small. On a small tetrahedral cell the movement is very light, and probably one of the greatest advantages in the Bell "compound tetrahedral" structure is that the resultant center of pressure shifts to no greater extent than for one cell itself. This tends to give an unusual stability to the entire structure.

Newton implicitly assumed that when a rectangular plate was moved through the air at an angle of inclination to the line of motion, the center of pressure and the center of the surface were always coincident. It has long been recognized, however, that this is not the case, and that the position of the center of pressure varies with the incident angle.

Joessel, in 1869, was the first to experimentally determine the variation of position of the center of pressure at different angles.[1] His experiments were conducted on square flat planes and he deduced as a result of his experiments the formulæ:

$$C = (0.2 + 0.3 \sin \alpha)\ L$$
$$d = (0.3 - 0.3 \sin \alpha)\ L$$

where C is the distance of the center of pressure from the front edge of the plane, α is the angle of incidence, L is the width from front to back of the plane, and d is the distance of the center of pressure from the center of surface. These formulæ indicate that the center of pressure varies from 0.5 to 0.2 of the distance from the front to the center of the plane.

In 1875 Kummer also conducted experiments on the position of the center of pressure.[2] The method of experiment adopted by him consisted essentially in finding the angle of inclination of the plane, corresponding to a series of fixed distances of the center of pressure from the center of figure.

The experiments conducted by Langley with the "counterpoised eccentric plane"[3] were also of this character. Both of these sets of experiments were on flat square planes, and their general results given in the table on this page show how closely they agree.

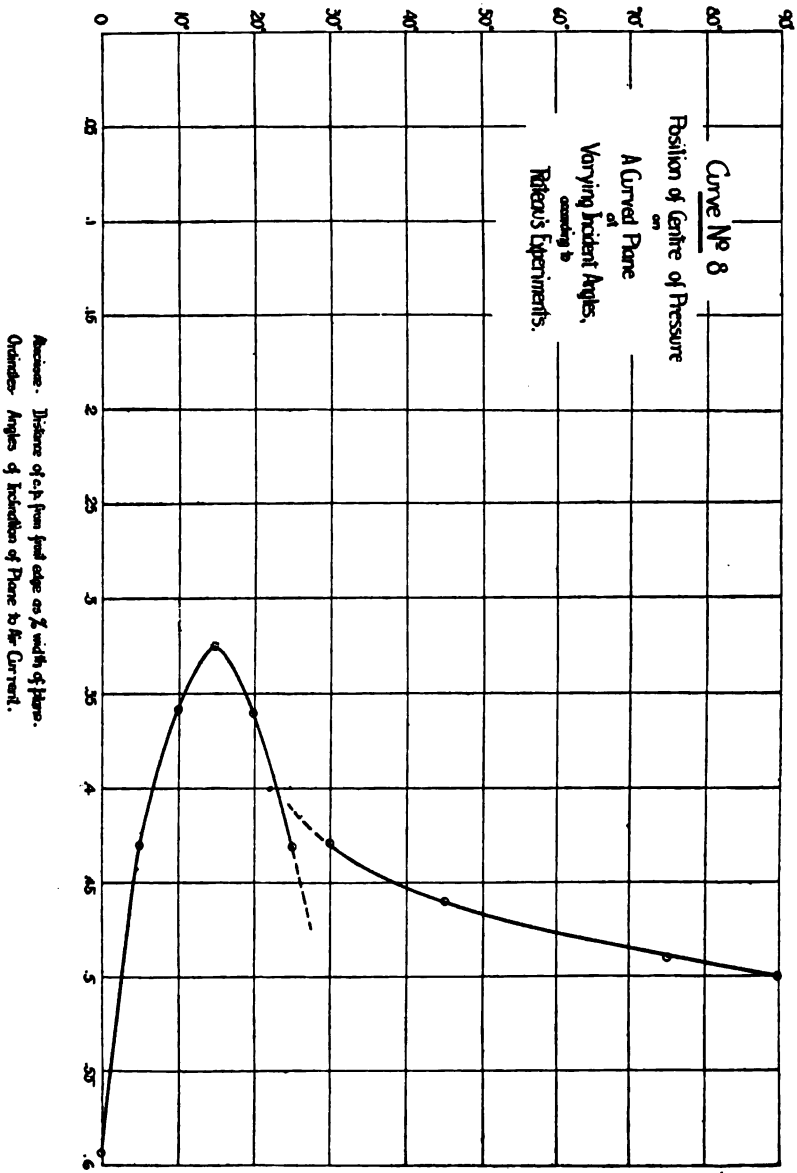
POSITION OF CENTER OF PRESSURE

Angle of plane with current.	Distance of c. p. from center of plane as percentage of side of plane. Langley.	Kummer.
90 deg.	0	0
78 deg.	.021	
77 deg.		.022
67.3 deg.	.042	
62 deg.		.044
55.8 deg.	.063	
52 deg.		.056
45 deg.	.083	
41 deg.		.067
28 deg.	.125	.089
21 deg.		.144
20.5 deg.	.146	

Neither of these experimenters obtained values for very low angles.

M. Rateau, in the aerodynamic experiments recently conducted by him, investigated the variation of position of the center of pressure on flat planes.[4] His results are shown graphically in Curve 7, and indicate that at 0 deg. and near 30 deg. there are regions of great instability. The results of Langley and Kummer are also plotted on this curve for comparison.

The movement of the center of pressure on curved surfaces is quite different from that on flat surfaces.

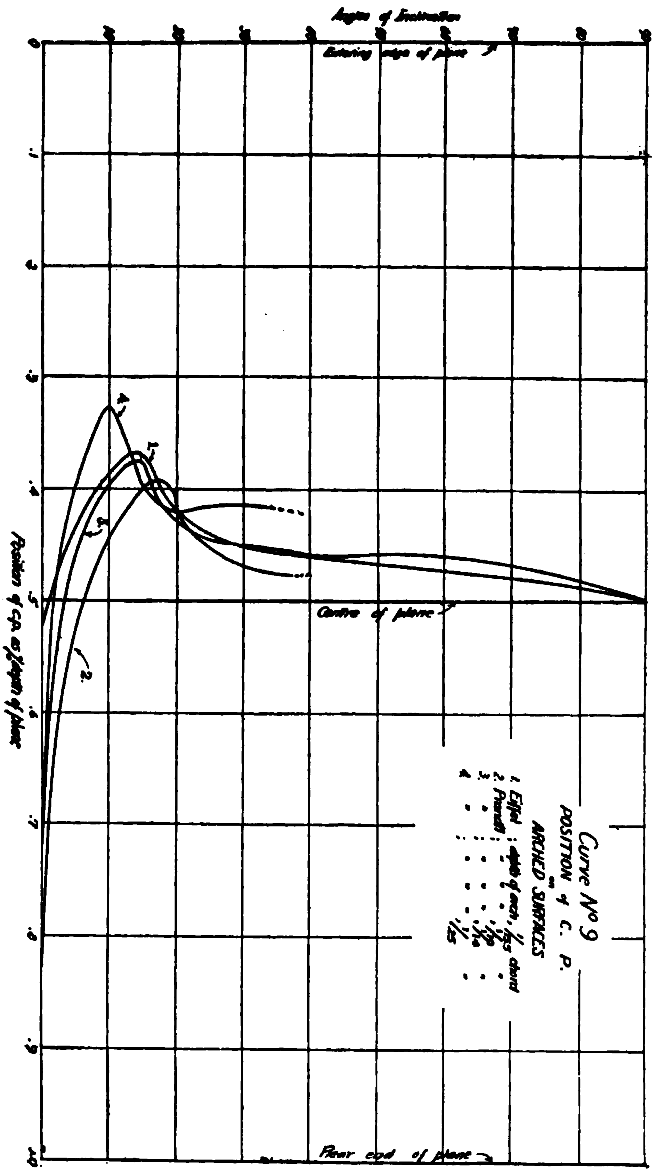

Curve No 8
Position of Centre of Pressure on A Curved Plane at Varying Incident Angles, according to Rateau's Experiments.
0
10°
20°
30°
40°
50°
60°
70°
80°
90°
.05
.1
.15
.2
.25
.3
.35
.4
.45
.5
.55
.6
Abscissae - Distance of c.p. from front edge as % width of plane.
Ordinates - Angles of Inclination of Plane to Air Current.

In deeply arched surfaces the center of pressure moves steadily forward from the center of surface as the inclination is turned down from 90 deg. until a certain point is reached, varying with the depth of curvature. After this point is passed a curious phenomenon takes place: the center of pressure instead of continuing to move forward with decrease of angle, turns rather abruptly and moves rapidly to the rear. According to Mr. Wilbur Wright, this action is due largely to the pressure of the wind acting also on the upper side of the arched surface at low angles. The action, however, is unmistakable, and has often been observed in practice.

The experiments of M. Rateau, already alluded to, also included an investigation of the movement of the center of pressure on an arched surface, the results of which are shown graphically in Curve 8. The reversal in movement is very apparent in the neighborhood of 15 deg. and shows strikingly how different the conditions of pressure on a curved surface at low angles are from those on flat surfaces. A region of instability at 30 deg., however, seems also to be present in this curved surface.

The 1910 Eiffel experiments on the curved surface, 900 millimeters × 150 millimeters, already referred to, included a determination of the movement of the center of pressure. The results are given in graph No. 1, on curve sheet No. 9. A reversal at about 15 deg. is here observed, but the backward movement is not as pronounced as in the Rateau determination.

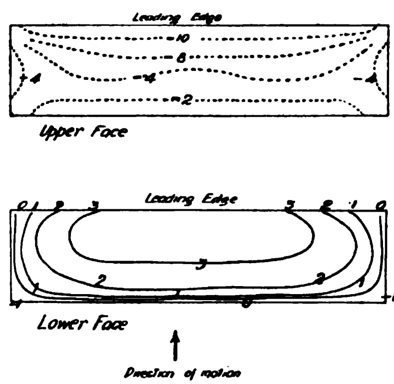
On curve sheet No. 9 are also given the results of the experiments of Prof. Prandtl,[5] on planes of different curvature. These show that as the depth of curvature is decreased the reversal point moves farther forward, and in addition, the reversal takes place at a lower angle and more suddenly. The backward movement, however, is greatest for the deepest curved surface (1/10). The results lead to the conclusion that because of the greater suddenness of reversal, very slightly curved surfaces are more dangerous than highly arched ones, but it must be borne in mind that the truly dangerous condition of movement of the center of pressure would be represented on the curve sheet by the most


Curve No 9
POSITION of C. P.
on ARCHED SURFACES
Entering edge of plane
Centre of plane
Rear end of plane

nearly horizontal line. This indicates that at angles of from 0 deg. to 5 deg. the 1/10 curve is the most unstable.

THE DISTRIBUTION OF PRESSURE

M. Eiffel also investigated the distribution of pressure over a curved plane set at 10 deg. Some of his results are shown in the diagram on this page, where 3, 2, 1, 0, — 1, and — 10, — 8, — 4, etc., are numerical quantities, indicating the relative value of the pressures, the distribution of which are shown by the contour-like lines on the surface. On line 3, for example, every point is at a pressure, three times as great as that of every point on line 1.



THE DISTRIBUTION OF PRESSURE ON A PLANE SURFACE (EIFFEL)

The dotted lines, —1 on the under surface, indicate a negative pressure at these points; and this leads at once to the conclusion that it is advisable to "round" the ends of the planes, as is done on the Blériot, Wright, etc.

The considerable negative pressure on the upper face at the front suggests possibly that in this region there is a pronounced Bernouilli effect.

[1]Joessel, Memorial du Genie Maritime, 1870.
[2]Kummer, Berlin Akad, Abhandlungen, 1875, 1876.
[3]Langley, "Experiments in Aerodynamics," Chapt. 8.
[4]Rateau, A., Aerophile, v. 17, p. 330, August, 1909.
[5] Prandtl, Mitt. Goettingen Aerodyn. Lab.; Zeit. fur Flug. v. Motorl., 1910.

CHAPTER VII.

THE EFFECT OF DEPTH OF CURVATURE AND ASPECT RATIO UPON THE LIFT AND DRIFT OF CURVED PLANES

THERE has been much discussion among those actively interested in aviation about the effect that varying the curvature of a plane or changing its aspect ratio has on the lift and drift. The experiments of Prof. Prandtl have done much to settle these questions, however, and their results are so forcibly brought out that many of them may well be considered conclusive.

DEPTH OF CURVATURE

Curve No. 10, page 69, shows the drift variation with angle of incidence, for three surfaces of different curvature, but all of the same size and aspect.

The results show that the drift resistance decreases as the depth of curvature decreases. In other words, under the same conditions, a flatter plane has a much less dynamic resistance than a highly arched one. It is largely for this reason that flatter planes are more suitable to a racing machine. It must be borne in mind, however, that these experiments were conducted on planes of circular curvature, and the conclusions arrived at are only applicable to such planes. Where the section is more like that of a bird's wing, very thick at the front, or where the greatest depth is within a third of the width (distance from front to back of a plane), from the leading edge, the conditions are likely to be quite different, especially at high velocities.

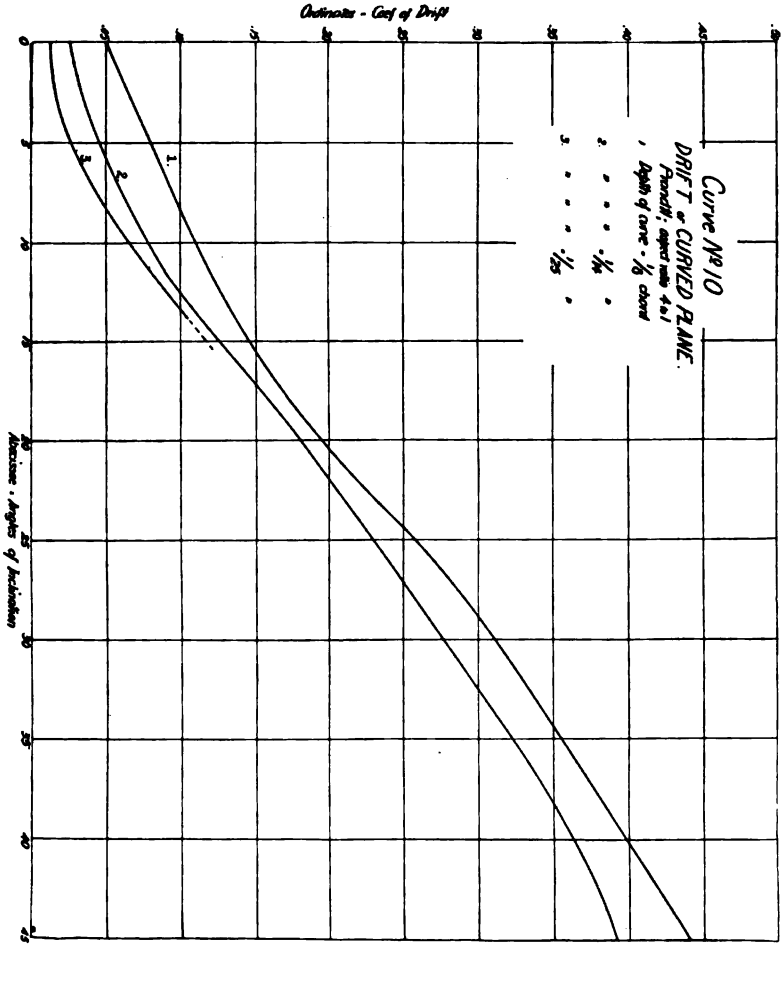
Curve No. 11, page 70, shows that the lift of a plane increases greatly as the curvature is made deeper. That a flatter plane lifts less than a highly arched, however, has long been surmised. The lift of the 1/14 plane appears greater at small angles than any of the others. This may be due to experimental errors.

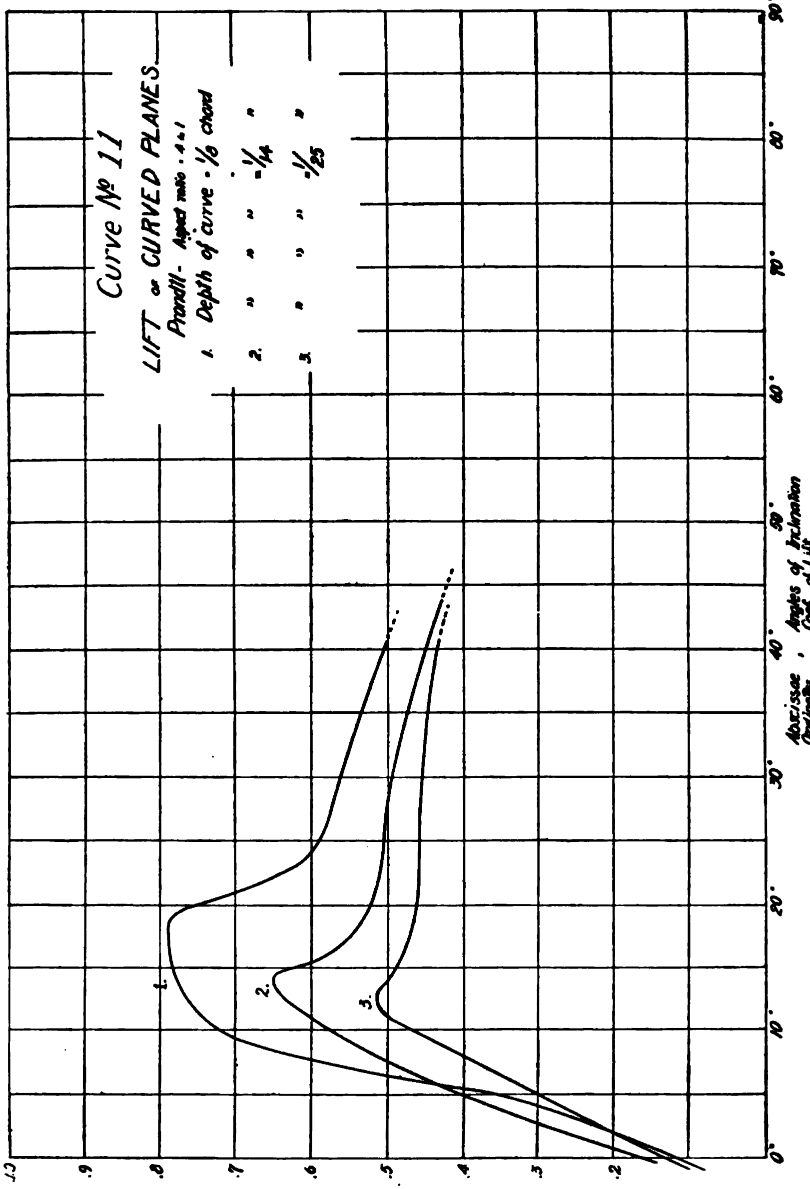
Curve No. 12, page 71, shows the ratio of lift to drift for planes of varying curvature, and it may be concluded from it that the ratio of L/D is greatest for the flattest plane, 1/25 depth. The angle at which L/D is greatest varies from the neighborhood of 4 deg. for the 1/25 section, to 9 deg. for the 1/10 section. There is therefore additional reason for using a nearly flat plane for a high-speed machine.

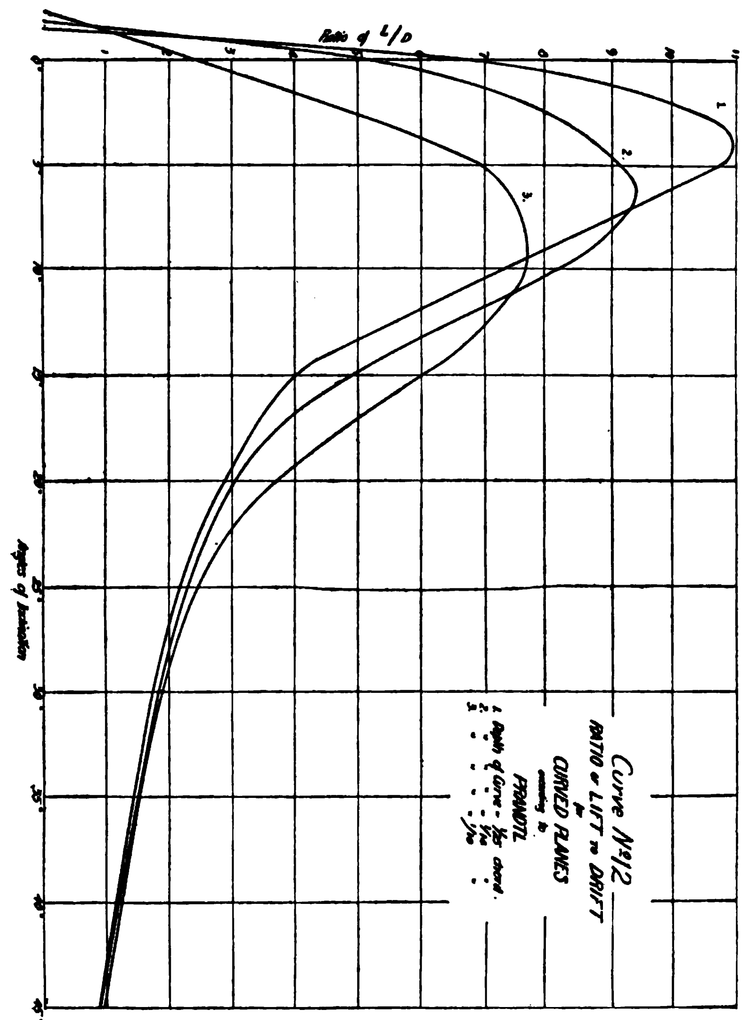
The author concludes from experiments of his own that the ideal section for high speed is a thick leading edge, and a nearly flat under face with a fairly well arched upper face, giving a considerable thickness, about one-third back of the leading edge. This gives all the advantages of a flat plane in reduction of drift, but increases the efficiency by reason of the fact that a well designed upper face will so "influence" and guide the air streams past the surface that few regions of discontinuity will exist. The thickness, however, must not be made too great because of the higher resistance caused thereby. The curved upper face will generate the well marked upward trend of the advancing current of air, a highly advantageous characteristic of curved surfaces that is very pronounced in all stream line photographs; it is even likely that this upward trend has much to do with the increased lift of curved surfaces in that the angle between the air stream and the chord of the surface is much greater than the angle of incidence, i. e., between the chord and the general line of motion of the air stream. Because of this greater angle, the pressure on the plane is increased, and this increased pressure largely turned into lift, the drift remaining about the same, thus giving a much higher efficiency.

Referring to the stream line photograph on page 48, a region of discontinuity is observed at the rear. trailing out from the rear edge, and obviously due to the sudden passage of the air stream past this sharp edge. This action certainly decreases the efficiency by increasing the resistance. It would appear, therefore, that a gentle upward reverse curvature of the rear edge might add to the efficiency.

Not long ago W. R. Turnbull conducted a series of experiments on differently shaped sections of planes,[2] and found that a section of this "reverse curve" type gave excellent lift and a


Ordinates - Coef of Drift
Abscissae - Angles of Incidence
Curve № 10
DRIFT of CURVED PLANE.
Prandtl; aspect ratio 4 to 1
1 Depth of curve - 1/5 chord
2 " " " 1/14 "
3 " " " 1/25 "
1.
2.
3.


Curve No 11
LIFT of CURVED PLANES
Prandtl - Aspect ratio : 4 = 1
1. Depth of curve - 1/6 chord
2. " " " = 1/14 "
3. " " " = 1/25 "
Abscissae ; Angles of Inclination
Ordinates ; Coeff. of Lift
1.
2.
3.


Curve No. 12
RATIO of LIFT to DRIFT
for
CURVED PLANES
PRANDTL
Ratio of L/D
Angles of Inclination

very low drift. Incidentally, he also found that in this kind of a surface, the movement of the center of pressure was very regular, and therefore gave much greater stability. The outer ends of the v. Pischof and Etrich monoplanes (see Part II, Chapter X) are turned up, somewhat in this fashion, and it is found that this disposition, suggested some years ago by Tatin, greatly adds to the stability.

ASPECT RATIO

There is little necessity for dwelling at length upon the advantage of a high aspect ratio, i. e., the ratio of the span of a plane to the depth, chord, or distance parallel to the direction of the air stream. That a broadly spreading plane of small chord gives a much better efficiency than a short span plane with its longest dimension from front to rear, has long been known.

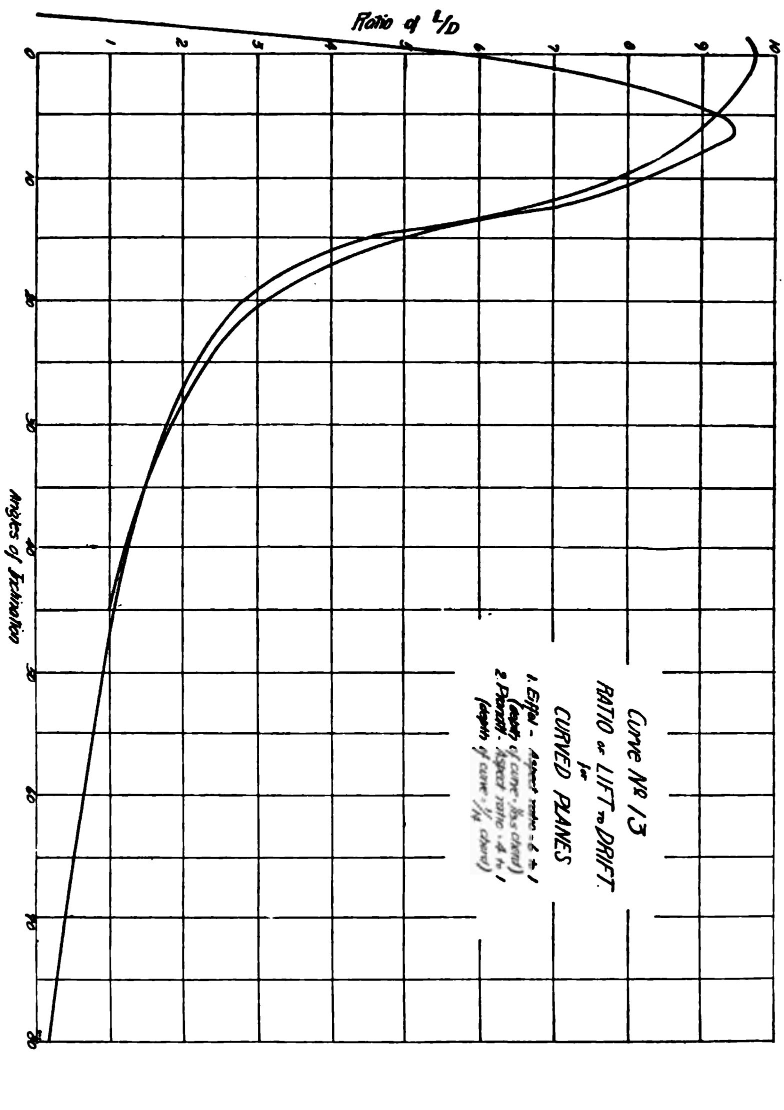
It is interesting, nevertheless, to compare the results of Eiffel and Prandtl on planes of different aspect ratio as is done in curve No. 13, on page 73.

Eiffel's plane measured 900 millimeters in span and 150 millimeters in depth, giving an aspect ratio of 6 to 1. Prandtl's plane measured 80 centimeters in span and 20 centimeters in depth, giving an aspect ratio of 4 to 1. The curvatures of the two planes were similar. Yet the ratio of lift to drift does not show any noticeable difference except at angles below 4 deg. At 0 deg. there is a very great difference, the plane with the high aspect ratio having a much higher efficiency.

In curve No. 14, page 77, are given the results of Prandtl's experiments on planes of the same curvature (3/40) but of different aspects. Here there is a very distinct variation, the ratio of lift to drift decreasing greatly as the aspect ratio is decreased. For the 5.25 to 1 plane, it is nearly 12, and for the 1 to 1 it is 4.9.

The different planes have their maximum values of L/D at about the same region, 4 deg. to 6 deg.

Comparing curves No. 13 and No. 14, it becomes at once evident that Eiffel's results for the 6 to 1, and Prandtl's for the 5.25 to 1, bear little resemblance. Prandtl's curve, although smaller


Ratio of L/D
Angles of Inclination
Curve No 13
RATIO of LIFT to DRIFT.
for
CURVED PLANES
1. Eiffel - Aspect ratio = 6 to 1
2. Prandtl - Aspect ratio = 4 to 1

in aspect, having a higher ratio of L/D than Eiffel's. The results are therefore not in good accord, and emphasis should be laid on this fact to show how even at this stage, two of the most prominent experimenters can differ in their results. Excepting in one or two points such as these, however, it must be acknowledged that the results of Prandtl, Eiffel, Rateau, Spratt, Lilienthal, Langley, and others, do bear each other out quite well.

Exactly why a high aspect ratio is so beneficial is not known, but it may possibly arise from two causes. First, there must be a leakage of air around the lateral edges of a plane, and naturally the smaller these edges the less the leakage. A long plane with a small span would permit of a much greater flow of air out past its sides than along under it and out at the rear; while a very broad plane with a small depth would have the air stream largely pass under it and out to the rear, and little leakage past the sides. This at once suggests that a shape of plane (in plan, not in section) could be designed in which all the advantages of a high aspect ratio are preserved without the excessively wide span, a shape something like that of the Paulhan biplane. (See Part II, Chapter XI, page 210).

The second advantageous characteristic of a high aspect ratio is not so well defined. It is a fact observable from the stream line photographs that the air stream passing under an inclined plane is gradually deflected until it leaves the region of the rear edge practically tangential to the surface. But, obviously, if it does leave tangentially or nearly so, there can be little or no lift in this region. The plane, therefore, is not so efficient, the drift of course being slightly decreased for this region (due to the lesser incidence), but the lift being decreased in very much greater proportion. The ratio of this "dead" region to the effective area in front of it would certainly be greater on a plane of low aspect ratio than on one of high aspect ratio.

[1] Prandtl, Mitt. Goettingen Aerodynamischen Laboratorium; Zeit. fur Flug. v. Motorl., 1910.

[2] Turnbull, W. R., "Forms and Stability of Aeroplanes," Sci. Am. Supp., v. 67, p. 68.

CHAPTER VIII.

NUMERICAL EXAMPLE OF THE DESIGN OF AN AEROPLANE

To ILLUSTRATE numerically the application of the theoretical matter and experimental data contained in the preceding chapters of this volume, the following example is given. Calculations in this kind of work need be made only to 5 or 10 pounds for lift, and 1 or 2 pounds for drift. Any refined calculation to hundredths or even tenths of a pound has no *raison d'etre.*

DESIGN OF A BIPLANE

Weight, speed and angle of incidence assumed: to find the area and dimensions of the planes and rudders and the motive power necessary.

Let $W =$ total weight (including operator) $= 1000$ pounds. Let the desired speed $V = 45$ miles an hour, and let the angle of incidence be assumed provisionally at 5 deg. We must first choose a type of curvature. This being a rather slow and heavy machine a 1/12 curve would answer well. A convenient aspect ratio such as 5½ to 1 must also be chosen, and depends primarily on the type of structure and materials to be used.

Since the lift must equal the weight W, we have, according to Lilienthal, for a 1/12 curve,

$$L^1 = 1000 = [(\cos 5 \text{ deg.} \times n) + (\sin 5 \text{ deg.} \times t)] \times P_{90}$$

and referring to the Lilienthal table, page 49, and to a table of natural trigonometric functions quite accurate enough to three places for this kind of work, we get cos 5 deg. $= 0.996$ and sin 5 deg. $= 0.087$. Then

$$L' = 1000 = [\ (0.996 \times 0.650) + (0.087 \times 0.014)\ ]\ P_{90}$$
$$= 0.648\ P_{90}$$
$$\therefore P_{90} = \frac{1000}{0.648} = 1550 \text{ pounds.}$$

Lilienthal's values for lift, however, especially at 5 deg., are now generally conceded to be too high for reasons explained in Chapter IV.

If we used Eiffel's results (see page 54), the values obtained are:

$$L = Ky \times SV^2$$

$$1000 = 0.00224 \times S\,V^2$$

whence $$L = \frac{0.00224}{0.00314}\,0.00314\,SV^2$$

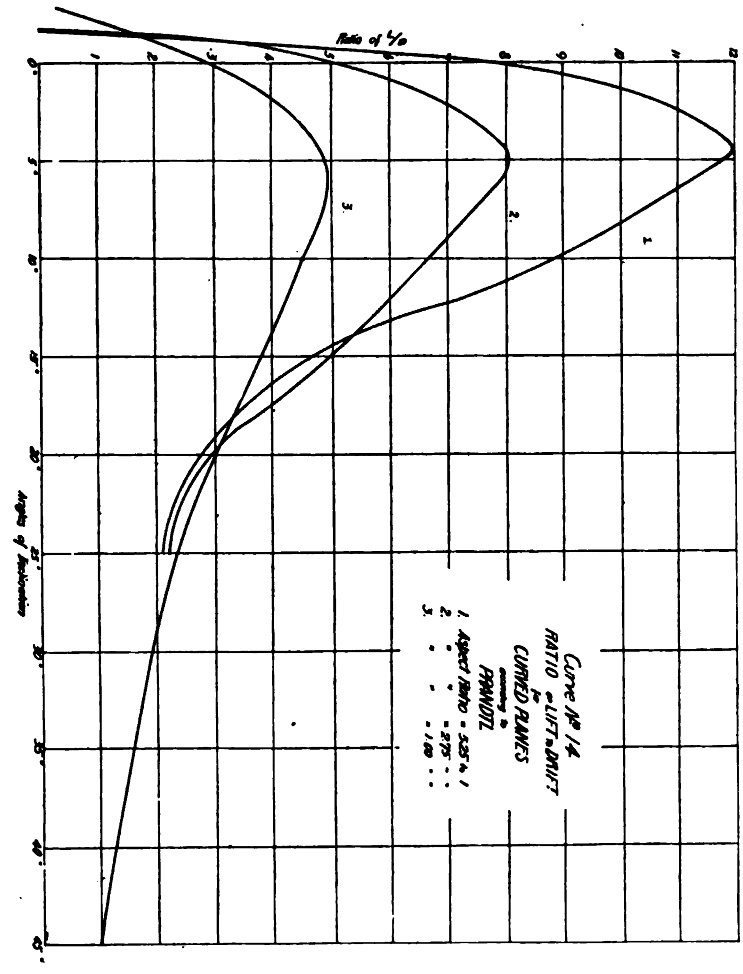
and $$1000 = 0.71\,P_{90},\text{ giving}$$

$$P_{90} = \frac{1000}{0.71} = 1410\text{ pounds.}$$

AT BELMONT PARK, OCT., 1910

A Farman biplane closely followed by a Blériot monoplane.

But in this case, it must be borne in mind that the aspect ratio is 6 to 1 and the curvature 1/13.5, both leading to a high lift, so that the value 0.71 is very likely 10 to 15 per cent too high.


Ratio of L/D
Angles of Inclination
Curve No 14
RATIO = LIFT ÷ DRIFT
for
CURVED PLANES
according to
PRANDTL
1. Aspect Ratio = 5.25 to 1
2. " " = 2.75 " "
3. " " = 1.00 " "

In Curve No. 10 are plotted the values of drift for a plane with a 1/14 depth of curvature. Although the aspect ratio is 4 to 1 for this surface, the effect of an increase of aspect ratio to a higher value would not appreciably alter the drift; it would only increase the lift. In Curve No. 14 are plotted the values of Lift/Drift for a plane having an aspect ratio of 5.25 to 1 and a curvature of very nearly 1/12. For 5 deg., L/D from Curve No. 14 equals about 12, and from Curve No. 10, it is seen that the drift coef. equals .04. Therefore the lift coefficient upon combining equals $12 \times 0.04 = 0.48$.

Then
$$L = 1000 = 0.48\,P_{90}$$
and
$$P_{90} = \frac{1000}{0.48} = 2080 \text{ pounds.}$$
Since
$$P_{90} = KSV^2 = 0.003\ \ S \times 2025$$
$$P_{90} = 6.075\ S \text{ or } S = P_{90}/6.075$$

which gives $S = 256$ square feet by Lilienthal; $S = 232$ square feet by Eiffel and $S = 345$ square feet by Prandtl.

The values of both Lilienthal and Eiffel are certainly very low, and to be on the safe side, we will use the more reliable results of Prandtl.

We may therefore say that the required area is 350 square feet.

This is the area necessary to give the lift of 1,000 pounds at 5 deg. and at 45 miles an hour.

The aspect ratio is to be in the neighborhood of 5½ to 1.

It has already been said that "rounding" the ends of planes is a very good practice. To do this we must take off about 10 square feet on each end of the otherwise rectangular planes. This means that our rectangular dimensions must give 40 square feet greater area, or 390 square feet. Each plane then should have the superficial dimensions of a rectangle 195 square feet in area.

The conditions are entirely satisfied by a biplane, the surfaces of which are rounded at the ends, 32 feet 6 inches in spread (maximum width side to side), and 6 feet 0 inches in chord (maximum distance front to back), giving an aspect ratio of 5.42 to 1.

This is a provisional set of values for the surfaces. If the aspect ratio or depth of curvature is to be changed, the corresponding changes in the constants will give a different P_{90} and a different surface, the choice of values. as in all kinds of en-

A GLIMPSE OF BLÉRIOT SHORTLY AFTER HIS START ON HIS HISTORICAL CROSSING OF THE ENGLISH CHANNEL, JULY 25TH, 1909

gineering practice, depending in great measure upon the experience, judgment and technical training of the designer.

P_{90} and the dimensions of the surface being known, the drift can now be calculated.

By Lilienthal, (see Table p. 49).

$D = [\ (n \sin 5 \text{ deg.}) - (t \cos 5 \text{ deg.})\ ] \times P_{90}$

$= [\ (0.650 \times 0.087) - (0.014 \times 0.996)\ ] \times 0.003 \times S \times V^2$

$= 0.042 \times 0.003 \times 350 \times 2025$

$= 90$ pounds.

Lilienthal's values for drift are generally thought to be quite good.

Using Eiffel's table (see p. 54) $Kx = 0.00025$, and

$D = 0.00025\ SV^2$

$= 0.00025 \times 350 \times 2025$

$= 177$ pounds,

a value that is perhaps a little excessive.

By Prandtl's results (see p. 69)

$D = 0.04 \times KSV^2$

$= 0.04 \times 0.003 \times 350 \times 2025$

$= 85$ pounds

a value that is low.

Lilienthal's value of the drift is quite reasonable; allowing a large enough factor of safety, we can call the drift 150 pounds.

This 150 pounds is the drift or aerodynamic resistance. To get the necessary thrust of the propeller, we must add to it the head resistance of the body and framing H and the frictional resistance F. Then, if we let $R =$ the total resistance to motion, obviously

$$R = D + H + F.$$
$$= D + K\ S\ V^2 + 2fS$$

To get the head resistance, the cross section of the machine must be reduced to an equivalent flat surface. It is unnecessary to go into the detail of this somewhat laborious computation, but it consists in estimating with a reasonable degree of accuracy:

1. The combined cross-section of wires, struts and framing, all projected on a vertical plane, perpendicular to the line of flight. The simplest way of obtaining this is to determine the cross-section per inch or per foot of the wires allowing 1/16 inch to ⅛ inch for vibration, and multiplying by the number of inches or feet of wire or cable. The same is done for the frame members and the cross spars.

2. The projected area of operator motor tanks, seat, etc.

All these are added together, and if we let this area be A, then

$$H = K\ A\ V^2$$
$$= 0.003 \times A \times 2025$$

In a machine of this size A is about 3 to 4 square feet at the most.

Then $H = 0.003 \times 4 \times 2025$
$= 24.3$ pounds.

The frictional coefficient f is obtained by interpolation from the Table on p. 58, for $V = 45$ and a 6-foot plane.

$$f = 0.0162$$

Then the frictional resistance

$$F = 2 \times 0.0162 \times 390$$
$$= 12.6 \text{ pounds}$$

The resistance of the main biplane cell alone is then:

$$R = 150 + 25 + 13$$
$$= 188 \text{ pounds.}$$

But we have not yet considered the rudders or keels, and their resistance is quite large. Their size in general is dependent upon their distance from the centers of gravity and pressure. If they are very far to the rear as in the Antoinette, then their size need be much less than if they were placed near the center of pressure. Their shape is largely a matter of personal taste. In any case, however, the governing principle in their design, is that they should never be so small, that in order to correct a very bad cant of the machine, they must be inclined at an angle as high as 25 deg. to 30 deg. The pressures at such angles especially on curved surfaces are unreliable, and likely to give only a drag, instead of a righting force.

RUDDER DESIGN

A very simple and efficient method of elevation rudder design is to determine approximately, as we can do from Prof. Prandtl's results, what the maximum movement of the center of pressure is from the normal position that it is supposed to occupy at 5 deg. and over, which the center of gravity is located.

In the diagram on this page, let AB = the main plane, C = the normal position of the center of pressure (and also the center of gravity), and CC^1 = the maximum backward movement of the center of pressure.

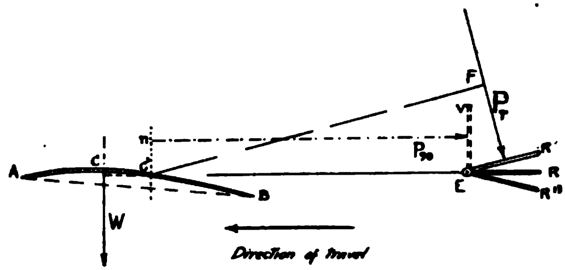


DIAGRAM SHOWING THE FORCES ON AN AEROPLANE SURFACE AB AND REAR ELEVATION RUDDER ER WHEN THE CENTER OF PRESSURE MOVES FROM C TO C^1

Let ER be the normal position of the elevation rudder (placed at the rear as on the Wright, etc.), and ER' ER'', its maximum movement for ascent and descent respectively. The worst movement of the center of pressure is the backward one at low angles. Assuming that C' represents the position for 0 deg., an inclination that no operator is likely to permit in ordinary flight, although he may greatly exceed it if he desires to gain speed by a sudden dive.

Since the center of gravity remains at C, it being assumed that the elevator is normally non-lifting, and that no lifting keels are provided, the weight of the entire machine will act through C, in the direction indicated. C', however, is now the center of support, so that we will have a moment about C', equal to $W \times$ the vertical distance between the action line of W and C', tending to rotate the system in a counter clockwise direction, i. e., the machine will tend to plunge. Incidentally the more sudden the movement of the center of pressure from C to C', the more dangerous will be this plunge, and there is great possibility that a sudden movement of this kind due to a quick change in the direction of a gusty head wind, has caused several of the recent accidents.

To correct this tendency to dive, we must make the elevation rudder of such size that when turned up to position ER', the pressure on it shown as $P_\gamma \times$ the vertical distance FC', will give a moment tending to rotate the system clockwise, and not only equal to, but a little greater than the moment of W due to its lever arm about C'. Obviously the farther back we place ER, the greater is

COUNT DE LAMBERT CIRCLING THE EIFFEL TOWER IN HIS FLIGHT OVER PARIS ON OCT. 19TH, 1909. HE USED A WRIGHT BIPLANE

its lever arm, and consequently for the same desired righting moment, the less need be the value of P_γ (i. e., the smaller the surface necessary). The reason why ER should never be turned at too great an angle, is easily shown. If it is turned to the position EV, then there is acting on it the normal force P_{90}. The action line of this force is $m\ n$, and its value not very much greater than P_γ. But its lever arm about C' is nC', and gives so small a clockwise moment that the rudder is practically ineffective.

This same analytical method is applicable to the determination of the conditions for the correction of the maximum forward movement of the center of pressure, causing the aeroplane to tip up and necessitating a movement of the rudder to ER''. It may also in a measure be extended to determine the size of direction rudders and of lifting keels.

Returning to our example, and referring to curve No. 9, p. 65, it is seen that the position of the center of pressure for a surface of this kind is about 44 per cent of the chord of the plane at 5 deg. from the front edge. This, then, is to be the position of the center of gravity. At 0 deg. it is seen that the center of pressure has moved back to a point 70 per cent of the chord from the front edge. Since the chord is 6 feet, the center of gravity is to be $0.44 \times 6 = 2$ feet 8 inches from the front edge, and of course at the center of the machine transversely. The movement of the center of pressure is to a point 0.70×6 or about 4 feet 2 inches from the front edge of the plane. The lever arm of the force W (see diagram p. 82) is then 1 foot 6 inches.

The weight is 1,000 pounds, therefore the counter clockwise moment tending to cause the machine to plunge is:

$$M = 1000 \times 1.5$$
$$= 1500 \text{ foot-pounds.}$$

To determine the size of rudder necessary, let us assume the type of structure we use, the strength of the material, and the weight we are limited to, permits of carrying the rudder framework far enough to the rear to make the distance between the center of ER and C' about 30 feet.

The maximum inclination of ER' above ER, is chosen at 15 deg. a reasonable limit.

Then the lever arm $C'F$ is approximately $C'F = 30$ feet $\times$ cos 15 deg.

$$= 30 \times 0.966$$
$$= 28.8 \text{ feet.}$$

The moment desired is to be in excess of 1,500 foot-pounds, and is taken at 1,600 foot-pounds.

$$M' = 1600 = 28.8 \times P_\gamma$$

Whence

$$P_\gamma = 1600/28.8 = 56 \text{ pounds.}$$

Assuming that this rudder is a flat plane, curve No. 2 p. 39 shows that when $\alpha = 15$ deg., $P_\alpha/P_{90} = 0.46$.

Then,

$P_{90} = P_\alpha/0.46 = 56/0.46 = 122$ pounds.

The size of surface can now be obtained.

Since $P_{90} = KSV^2$

$$S = P_{90}/KV^2 = 122/0.003 \times 2025$$
$$= 122/6.075 = 20 \text{ square feet.}$$

A very good shape of rudder therefore is a plane 10 feet spread and 2.5 feet depth, rounded at the corners.

If the aeroplane is to be used for speed only, this size could be slightly reduced. If it is to be used for fancy volplanes and spirals, it would certainly be wise to increase its size.

The dynamic resistance of this rudder is,

$$D_\gamma = P_\gamma \sin 15 \text{ deg.}$$
$$= 56 \times 0.259 = 14.5 \text{ pounds.}$$

MOTIVE POWER, ETC.

The extra resistance of the direction rudder, etc., may be taken roughly at 15 pounds. Then the total resistance is equal to:

$$R^1 = D + H + F + D_\gamma + 15$$
$$= (150) + (25) + (13) + (14.5) + (15)$$
$$= 217.5 \text{ pounds.}$$

This is the actual active thrust of the propeller, T, necessary to keep the machine in flight. if all these resistances acted at once, a condition that is possible.

The power required is the force $\times$ the distance moved per unit time.

$$\text{Power} = T \times V = 220\ V$$

expressed in foot-pounds per minute, when T the thrust is given in pounds, and V in feet per minute.

$$V = 45 \text{ miles per hour}$$
$$= 3960 \text{ feet per minute}$$

$$\therefore \text{Power} = 220 \times 3960 = 871{,}200 \frac{\text{ft. lbs.}}{\text{min.}}$$

$$1 \text{ Horse-power} = 33{,}000 \text{ ft. lbs./min.}$$

$$\therefore \text{Horse-power} = \frac{871{,}200}{33{,}000} = 26.4 \text{ horse-power.}$$

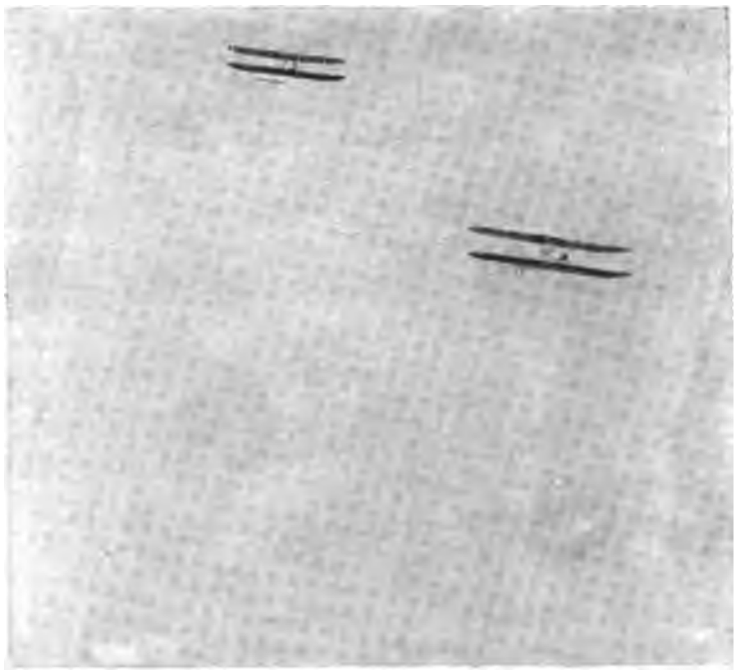
This is all the power necessary in the motor if the generation and transmission of the power were perfect. This is never the case. The propeller delivers roughly only 75 to 80 per cent of the power put into it. The motor itself and the transmission may cause another 5 per cent loss. Therefore, to obtain the power of the motor necessary, at its ordinary commercial rating, we may consider the system 70 per cent efficient.

This gives the horse-power of motor

$$= \frac{26.4}{0.7} = 38 \text{ horse-power.}$$

Therefore, for this machine a 40 horse-power motor will be amply sufficient. However, if great quickness and ease of starting is desired, or if the machine is to be flown at a high altitude, more power will be needed.

In order to design the propeller, we may assume the r. p. m. of the motor at 800. In propeller design, if it may be called such, practical experiment is infinitely more successful than volumes of theoretical calculations. The propeller industry is well advanced, and many of the propeller manufacturing concerns have finally been enabled by experiment to construct propellers suitable to different types of machines and speeds with great success. It is hardly necessary to go into the shape, pitch, or form of the blades here, as these points are largely matters of personal experience, and individual conditions. We may, however, obtain a rough idea of the diameter necessary by applying the Drzewiecki method, one of several that works out reasonably well, and given in full in his "Des Helices Aeriennes" (1909).



"THE HEAVENLY TWINS"

Johnstone and Hoxsey as they were popularly called at Belmont Park, Oct. 1910, climbing for altitude.

The two useful equations of this elaborate theory are:

$$m = \frac{V}{2\pi n}$$

$$\text{and } d = m \times 10$$

Where m is a constant called the "modulus," V = the velocity in meters per second, n = the revolutions per second, and d = the diameter of the propeller in meters. Converting the values we already have into their proper units, we get:

$$V = \frac{66}{3.28} = 20 \text{ meters per second.}$$

$$n = 13 \text{ r. p. s.}$$

Then $M = \frac{20}{2\pi \times 13}$

$$= \frac{20}{6.28 \times 13} = 0.245$$

and

$$d = 0.245 \times 10 = 2.45 \text{ meters}$$

$$= 2.45 \times 3.28 = 8 \text{ feet.}$$

SUMMARY

In this manner we arrive at the design of a biplane with the following characteristics:

Supporting Area = 350 square feet.
Spread = 32 feet 6 inches.
Chord = 6 feet.
Angle of incidence = 5 deg.
Depth of curvature = 1/12 chord.
Weight = 1000 pounds.
Elevation rudder = 10 feet by 2 feet 6 inches, placed 30 feet to rear, and non-lifting.
Motor = 40 horse-power 800 r. p. m.
Propeller = 8 feet in diameter.
Aspect ratio = 5.42 to 1.
Speed = 45 miles per hour.
Pounds carried per horse-power = 25.
Pounds carried per square foot of surface = 2.86.

The details of the controlling devices, transverse control, shape and position of rudders, propeller, motor, operator, etc., and the type of mounting are matters of personal choice. In Part II, the different dispositions used on the various successful machines are given in detail. In Part III, their advantages and disadvantages are discussed.

This example, however, indicates with what a degree of success an aeroplane may be designed, by the use of the most elementary mathematics combined with experimental values of the pressures on aeroplane surfaces.

In a monoplane, the process of design would be similar in every respect. The monoplane has, in general, less head resistance than the biplane, a modification which means that for the same power, a greater speed can be obtained and therefore a smaller surface is needed for support.

PART II.

DETAILED DESCRIPTIONS OF THE NOTABLE AEROPLANES

CHAPTER IX.

INTRODUCTION

The rapid progress that has been made in the practical application of the principles of Aerodynamics is almost unparalleled in the history of science. Within a year, the number of men making extended flights has increased so greatly, that we are warranted in classing artificial flight with other established means of locomotion.

The development of the aeroplane has been accompanied by the improvement of the dirigible balloon or aeronat, as technically termed; and the advance of both can undoubtedly be traced to the combination of high power and low weight offered by the gasoline engine.

In the case of aeronats, however, as early as 1884 the non-rigid type that we have to-day had been practically developed in the dirigible "La France," built by Col. Renard; and although much progress has been made, it has been more in the line of actual construction than in the development of any new principles.

The successful aeroplanes which have been evolved, although similar in their fundamental characteristics, have begun to vary from each other in many important details of size, arrangement and efficiency of parts. It seems, therefore, that we are at a stage where an examination of these various types for the purpose of comparison, and a discussion of their distinguishing features, merits, and demerits would prove of value.

The order in which the types are taken up is merely a convenient alphabetical one adopted here, and is not based on any quality of the machines. The biplanes and the monoplanes are separated, as they represent two distinct systems.

Many other systems of heavier-than-air machines have been constructed, including several triplanes and some extremely interesting helicopters and ornithopters, but as yet none of these has demonstrated successful flying qualities, except the Roe triplane.

For the purpose of more clearly showing the variations in size of the different types, detailed and dimensioned plans and elevations of each machine are given. Most of these are drawn to the same scale, thus establishing a direct graphic comparison of the types.

It is to be borne in mind that inasmuch as aviators are constantly changing and rechanging the dimensions of their machines, without recording such alterations, many of the dimensions given here are necessarily approximate. In all cases, however, the most recent and accurate data as furnished by the large number of references consulted, as well as by close personal inspection, have been made use of.

DEFINITIONS

In the science of Aviation it has been necessary to use a number of new terms.

By "supporting plane" is meant the main lifting surface as distinguished from all auxiliary or stabilizing surfaces.

The term "direction rudder" refers to the movable vertical surface used for steering to right or left, while the "elevation rudder" is that horizontal surface which is used for steering up or down.

"Transverse control" is the device used for the preservation of lateral balance in wind gusts, and for artificial inclination when making turns.

"Keels" are fixed surfaces exerting neither lifting effect nor rudder action.

"Spread" is the maximum horizontal dimension perpendicular to the line of flight, while "depth" is the dimension of the plane parallel to the line of flight.

By "aspect ratio," is meant the ratio of spread to depth, a means of defining the shape of surface.

"Fuselage" is a long narrow girder-like frame, often containing the motor seat, etc. It could be called the "backbone" or "spine" of a monoplane.

"Empennage" is a keel or fin, similar in character to the tail of an arrow.

"Nacelle," is a boat-like enclosed body, containing the seat, motor, etc., but it is distinguished from "fuselage" in that it plays no part in holding the rigidity of the structure.

A "tractor," screw pulls a machine (as on the Antoinette), while a "propeller" screw pushes a machine (as on the Wright biplane). The term "propeller," however, generally refers to both kinds of screws.

A plane is said to be at a "dihedral angle," when both sides are inclined upwards (positive) or downwards (negative) from the center.

"Angle of Incidence" is the angle between the chord of the plane and the relative direction of the air stream. (see Part I). Often the term "incidence," alone, is used in reference to this angle.

"Fusiform," "stream-line form," "spindle-shaped," are terms descriptive of the torpedo-like shape of a body that gives small resistance.

The "Mounting," or "chassis," is the apparatus or framework upon which the aeroplane rests, starts, and alights.

"Camber" is the rise in the arching of a curved plane (see p. 46).

"Chord" is identical with "depth."

"Ailerons," or "wing-tips" are small auxiliary planes used to preserve the side-to-side balance of an aeroplane.

"Loading" is a factor indicating the load in pounds that is carried per square foot of supporting surface.

Monoplanes at Rest and in Flight

CHAPTER X.

IMPORTANT TYPES OF MONOPLANES

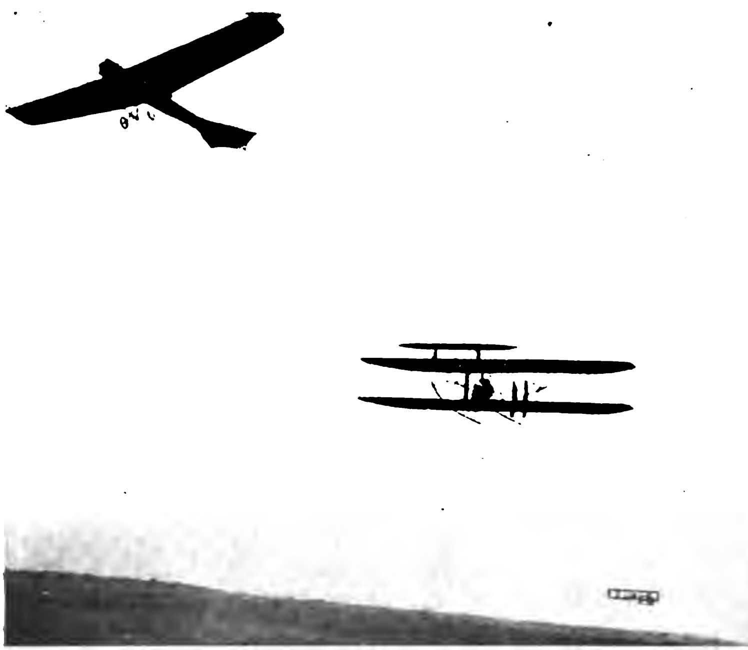
Monoplanes exhibit almost as great a variety of forms as biplanes, and by actual statistics it appears that the number of monoplanes flying, is far greater than the number of biplanes, especially in France. This is very likely due to their greater cheapness and simplicity of structure and the higher speed generally attainable.

As in biplanes, there are many prominent types that bear such close resemblance to types described here, that they need not be separately considered. The Albatross monoplane is a duplicate of the Antoinette with the exception that it is fitted with a Gnome motor. The Deperdussin and Regy recall the Hanriot, while the Minima and Montgolfier are similar in size and aspect to the Santos-Dumont. The Humber, Avis and Morane-Saulnier, all more or less resemble the Blériot, and the Vollmoeller is very much like the Tellier.

The eighteen types of monoplanes described in the following paragraphs are:

1. Antoinette
2. Blériot XI.
3. Blériot XI. 2bis
4. Blériot XII.
5. Blériot "Aero-bus"
6. Dorner
7. Etrich
8. Grade
9. Hanriot
10. Nieuport
11. Pfitzner
12. Pischof
13. R. E. P. (1909)

14. R. E. P. (1911)
15. Santos-Dumont
16. Sommer
17. Tellier
18. Valkyrie



THE ANTOINETTE MONOPLANE PASSING A WRIGHT AND A VOISIN

The propeller may be seen whirling at the front. The bird-like appearance is striking.

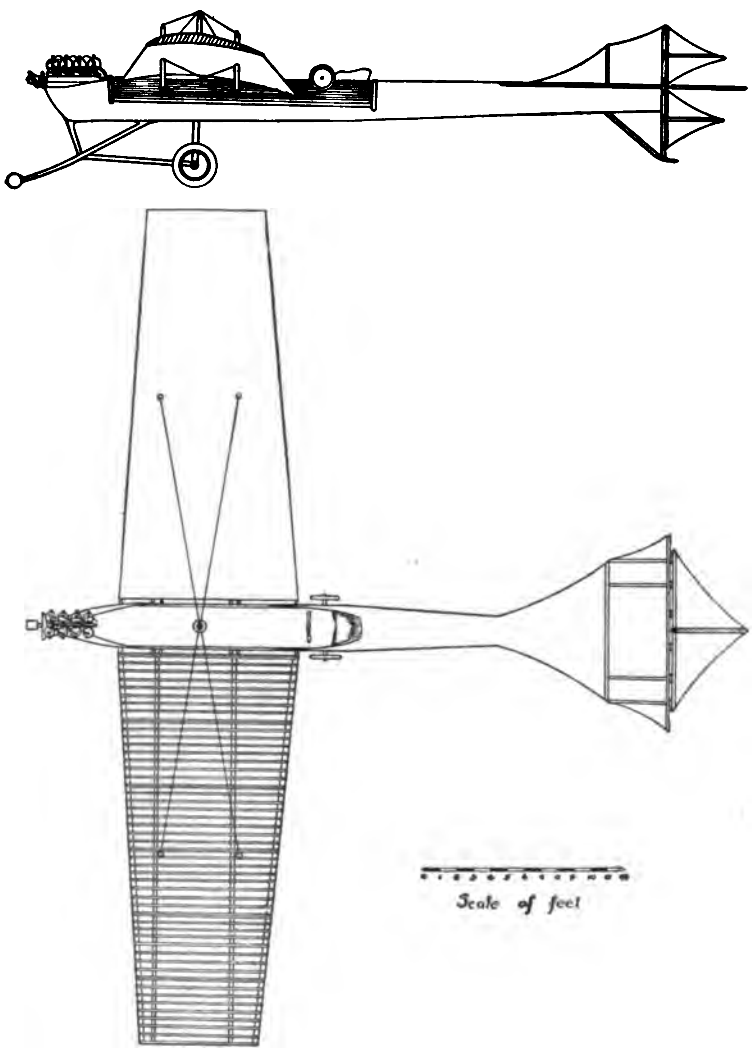
1. THE ANTOINETTE MONOPLANE

M. Levavasseur, designer of the Antoinette motor boats, is credited with the design of this type. After building some experimental machines, notably the Gastambide-Mengin monoplane, the "Antoinette IV." was built for M. Latham. This machine was controlled transversely by means of wing tips, while at present the warpable surface control is used. The Antoinette is very large and remarkably well built from an engineering standpoint, and has been operated very successfully by M. Latham in exceptionally high winds. Messrs. Kuller, de Mumm, Thomas, and Labouchère, have also flown monoplanes of this type, and several have been purchased by the French army. The Antoinette, because of its un-

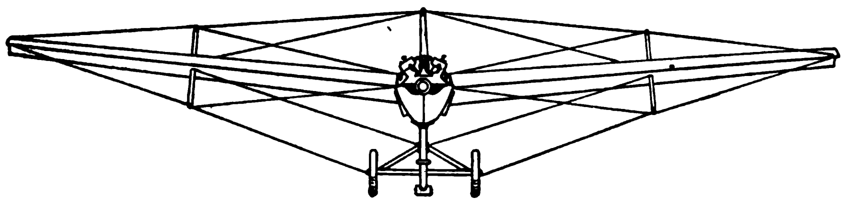
LATHAM'S ANTOINETTE SOARING ABOVE THE TREES IN THE INTERNATIONAL CUP RACE AT BELMONT PARK. OCT. 29TH, 1910

usual gracefulness always attracts a great deal of attention and admiration.

The Frame.—A long narrow frame of cedar, aluminum and ash carries at its front portion the main plane, at the extreme front end the propeller, and at the rear the rudders. At the bow the frame resembles the hull of a motor boat, while at the rear it is built in the form of a triangular latticed girder.



SIDE ELEVATION AND PLAN OF THE ANTOINETTE



Front Elevation of the Antoinette

M. Hubert Latham Seated on the Antoinette Monoplane

The left hand wheel seen here governs the warping of the planes. The wires leading from the drum are distinctly visible.

The Supporting Plane.—The carrying plane consists of a single surface divided into two halves of trapezoidal shape set at a slight dihedral angle and constructed of rigid trussing nearly 1 foot thick at the center, covered over and under with a smooth, finely pumiced silk. The plane is braced also from a central mast.

The spread is 46 feet, the average depth 8.2 feet, and the surface area 370 square feet.

The Direction Rudder.—The direction rudder consists of two

A 100-H. P. ANTOINETTE

Note the boat-like bow, the radiator along the sides of the body, and the searchlight.

vertical triangular surfaces at the rear, of 10 square feet area. They are moved jointly by means of wire cables running from a lever worked by the aviator's feet. When this pedal, which moves in a horizontal plane, is turned to the left the aeroplane will turn to the right, although in some cases the opposite disposition is used.

The Elevation Rudder.—The elevation rudder consists of a single triangular horizontal surface placed at the extreme rear, and 20 square feet in area. It is governed by cables leading from a wheel placed at the aviator's right hand. To ascend, the wheel is turned up. This causes the inclination of the elevation rudder with regard to the line of flight, to be decreased and the machine, therefore, rises.

Transverse Control.—The transverse equilibrium is corrected by warping of the outer ends of the main plane very much as in the Wright machine. But the front ends are movable and the rear ends rigid throughout in the Antoinette, while the opposite is the case in the Wright biplane.

The wheel at the aviator's left hand, through cables and a sprocket gear, placed at the lower end of the central mast, controls the warping. For correcting a dip downward on the right the right end of the wing is turned up, and at the same time the left end is turned down, thus restoring balance.

The controlling apparatus is described fully in Chapter XIII.

Keels.—At the rear, leading up to the rudders, are tapered keels, both horizontal and vertical, that add greatly to the bird-like appearance of the aeroplane.

Propulsion.—A 50 horse-power, 8-cylinder Antoinette motor, placed at the bow, drives direct a two-bladed Normale, wooden, propeller of 7.25 feet diameter and 4.3 feet pitch at 1,100 revolutions per minute.

The Seat for the aviator is placed in the frame back of the main plane. A seat for a passenger is provided in front of and a little below the aviator's seat.

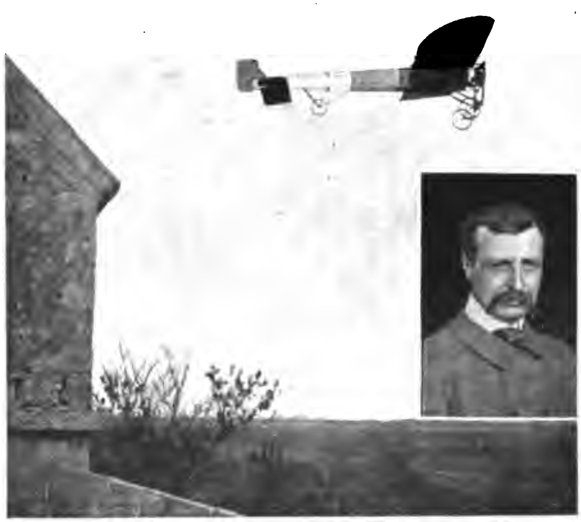
The Mounting is essentially on a large pair of wheels fitted to a pneumatic spring, and placed at the central mast. In addition a single skid to protect the propeller when landing is placed in front, and another is attached in the rear.

Weight, Speed, Loading and Aspect Ratio.—

The total weight is from 1,040 to 1,120 pounds; the speed is 52 miles per hour; 22.4 pounds are lifted per horse-power, and 3.03 pounds per square foot of supporting surface. The aspect ratio is 5.6 to 1.

Recent Alterations.—The Antoinette has been slightly altered. The spread is now 49.3 feet, the area 405 square feet, and the total weight from 1,200 to 1,350 pounds. Twenty-seven pounds are lifted per horse-power and 3.33 pounds per square foot of surface. The aspect ratio is 6 to 1. A new 100 horse-power type is also being used for racing.

References.—Aerophile, v. 17, pp. 7, 488; Flight, v. 1, pp. 662, 681; Aeronautics, v. 4, p. 63; SCI. AMERICAN, v. 100, p. 352; Rev. de l'Av., v. 4, p. 27; La Nature, v. 37, pp. 49, 329; Zeit. für Luftschiff, v. 13, p. 890; Encyl. d'Av., v. 1, p. 1; La Vie Auto., v. 9, p. 729; Flug Motor Tech., No. 22, p. 10; Boll. Soc. Aer. Ital., v. 6, p. 288; Zeit. Ver. Deut. Ing., v. 53, p. 1759; Genie Civil, v. 55, p. 340.



THE BLERIOT XI IN FLIGHT

M. Louis Blériot, its designer and pilot, the real "father" of the monoplane.

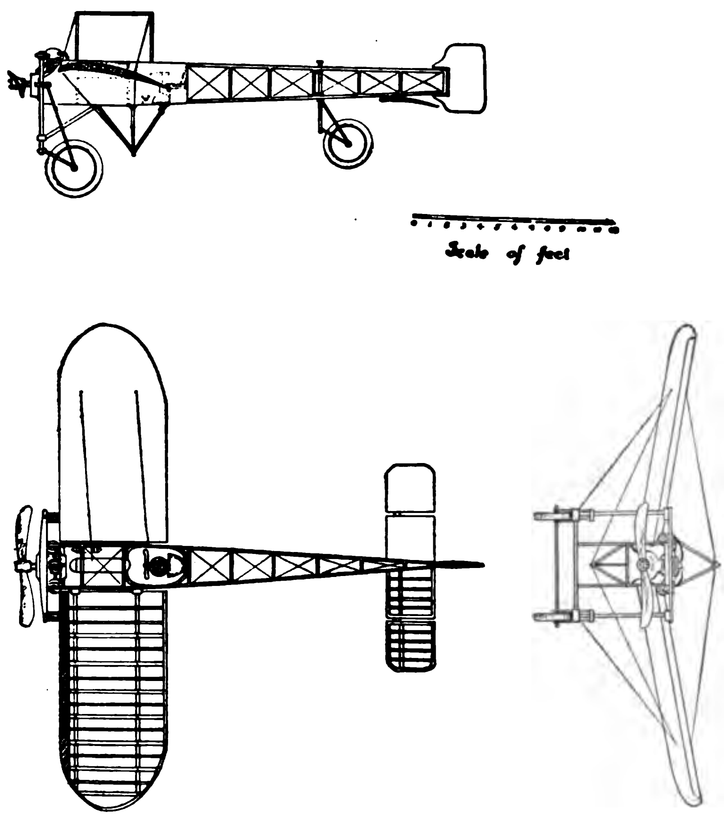
2. THE BLERIOT XI. MONOPLANE

In 1906 M. Louis Blériot constructed and operated the first successful monoplane in the world. He subsequently built type after type, and finally in 1908 succeeded in making several brilliant and extended flights in his large monoplane "No. 8 Bis." Since then he has become world-famous by his flight of July 25th,

CHAVEZ CLIMBING OUT OF HIS BLERIOT XI BIS.

This gives a close view of the central fuselage. Just back of and below Chavez may be seen the seat, control column and a barograph. Part of the planes and one blade of the propeller are also visible. Note the rocker arm for warping and wires leading to the *cloche*, below the fuselage.

1909, when he crossed the English Channel, starting from Calais, and landing near Dover. This flight was accomplished in the No. XI. type monoplane, a small one-passenger machine, which is very simple, and has become extremely popular. Among the noted avi-



THE BLERIOT XI (CROSS CHANNEL TYPE) PLAN AND ELEVATIONS

ators who have flown this aeroplane type are also Delagrange, Le Blon, Aubrun, Morane, Leblanc, de Lesseps, Balsan, and Guyot. Over 300 of these machines have been manufactured and sold by M. Blériot since September, 1909.

The Frame.—The frame consists essentially of a long central body upon which the planes and rudders are attached. This central framework is very lightly but very strongly built of wood, and is cross-braced with wires throughout.

The Supporting Plane.—The main plane is situated near the front, and divided into two halves, each mounted on either side of the central frame by socket joints. The halves of the plane are easily detachable here, and when not in use are dismounted and placed in a vertical position along the frame, thus occupying little room.

The surfaces consist of ribs covered both above and below by Continental rubber fabric. Their curvature is more pronounced than in most other types, and a sharp front edge is obtained by the use of aluminum sheeting. The two halves are at a slight dihedral angle.

The dimensions of the plane are spread 28.2 feet, depth 6.5 feet, and surface area 151 square feet.

The plane is braced above and below by wires from the central frame.

Direction Rudder.—The direction rudder consists of a small surface 4.5 square feet in area placed at the extreme rear. Wire cables leading to a foot lever controlled by the aviator govern the movement of this rudder. For turning to the right, for example, the aviator turns this lever by his feet to the right or left, depending on the disposition installed.

The controlling apparatus is described fully in Chapter XIII.

Elevation Rudder.—The elevation rudder is divided into two halves, one mounted at each extremity of a fixed horizontal keel. The rudder is 16 square feet in area. It is operated by the front and back motion of a "bell crank" or *cloche,* as it is called. This latter device is a universally pivoted lever, in front of the aviator, and in a normal position is vertical. At the lower extremity is attached a bell-shaped piece of metal, affording a means of attachment for the wires, and at the same time covering them to avoid their entanglement in the aviator's feet, etc. To ascend the aviator pulls this lever toward him, and to descend he pushes it away.

Transverse Control.—The lateral equilibrium is controlled by means of the warping of the main plane. The structure of this plane enables it to be warped, as in the Wright machine, but in this case about the base of each half, which is rigidly attached to the frame by the socket joints. The two halves are warped inversely by the side-to-side motion of the *cloche.* If the machine should tip up on the right, then the *cloche* is moved to the right. This increases the incidence of the lowered side and at the same

MOISANT ON HIS BLÉRIOT XI BIS RETURNING FROM HIS FAMOUS STATUE OF LIBERTY FLIGHT, BELMONT PARK, OCT. 30TH, 1910

time decreases that on the raised side, thus righting the machine. The combination of this side-to-side motion of the bell-crank, with the movement of the foot lever controlling the direction rudder, is used in turning.

Keels.—To preserve the longitudinal stability, a single fixed horizontal keel is placed at the rear. Its area is 17 square feet.

Propulsion.—At the front of the central frame is placed the motor, originally a 3-cylinder Anzani, developing 23 horse-power. This motor drove direct at 1,350 r.p.m. a Chauviere wooden propeller, two-bladed, 6.87 feet in diameter and 2.7 feet pitch. Several of the more recent aeroplanes of this type have been fitted with Gnome 50 horse-power rotary engines, similarly placed, and driving 7½ foot propellers.

The Seat is in the frame back of the main plane.

The Mounting consists of two large rubber-tired wheels at the front, mounted on an elastic chassis. The springs are made of thick rubber rope, and afford great elasticity and strength with small weight. There is also a small wheel at the rear.

Weight, Speed, Loading and Aspect Ratio.—

The total weight is from 650 to 720 pounds and the speed was at first 36 miles per hour; when a Gnome motor is used a speed

THE 14-CYL. 100-H. P. GNOME MOTOR OF CLAUDE GRAHAME-WHITE'S BLERIOT RACER WITH WHICH HE WON THE GORDON-BENNETT CUP RACE ON OCT. 29TH, 1910, AT BELMONT PARK

of 48 miles per hour is attained; 14.4 pounds are lifted per horse-power and 4.5 pounds carried per square foot of surface. The aspect ratio is 4.35 to 1.

The regular one-passenger type of this monoplane has further been altered to the new No. XI. *bis.* in which the sectional curvature of the planes is made very nearly flat on the underside. This change has been found to decrease the dynamic or drift resistance of the machine without seriously decreasing the lift. The speed has been increased to about 52 miles an hour. The spread is 28½ feet and the area 160 square feet.

There are two new models of this machine which have been very successful. They are the No. XI. 2*bis*. a two or three-passenger machine, and the No. XI. racing model.

The No. XI. racing model (*type de course*) is the machine upon which Leblanc recently established the speed record of the world by flying at almost 69 miles an hour, and with which Grahame-White won the 1910 Gordon-Bennett Cup Race.

This machine has a very short body, flat planes, and a reinforced frame. The surface has been reduced to 129 square feet, and the machine is equipped with one of the new 14-cylinder 100 horse-power Gnome motors. The total weight is about 750 pounds. Only 7.5 pounds are carried per horse-power, and as much as 5.76 pounds are lifted per square foot of surface.

References.—Zeit. Ver. Deut. Ing., v. 53, p. 1574; Aeronautics, v. 5, p. 118; Aerophile, v. 17, pp. 102, 106, 129, 318, 488; Encycl. d'Av., v. 1, pp. 3, 72, 92; Flug. Motor Tech., N. 22, p. 10; No. 23, p. 7; No. 25, p. 14; Flight, v. 1, p. 45?; Boll. Soc. Aer. Ital., v. 6, p. 288; Locomocion Aerea, v. 1, p. 78; La Vie Auto, v. 9, p. 729; La Nature, v. 37, p. 32?; SCI. AMERICAN SUP., v. 68, p. 136; Bracke, A., "Les Monoplans Blériot"; Glugsport, No. 24, p. 685; Genie Civil, v. 55, pp. 260, 344.

3. BLERIOT XI. 2 BIS

This machine, better known as the "type militaire," resembles in detail the other Blériot products, but differs greatly in size, in the fact that it is a two-seater, and in the construction of the fan-shaped tail.

Like all the new Blériot products, the dashboard in front of the seats is equipped with many of the new devices, such as recording barographs, speed counters, inclinators, folding map cases, speedometers, gages, and even thermos bottles, an equipment that indicates the rapid trend of progress in aviation more forcibly than anything else.

Many of the famous trips of the past year by Moisant (Paris to London), Morane, Drexel, and others, have been made on this type,

The Frame.—The frame is exactly similar in character to the Blériot XI. *bis* frame, excepting that it is shorter in length and built more heavily.

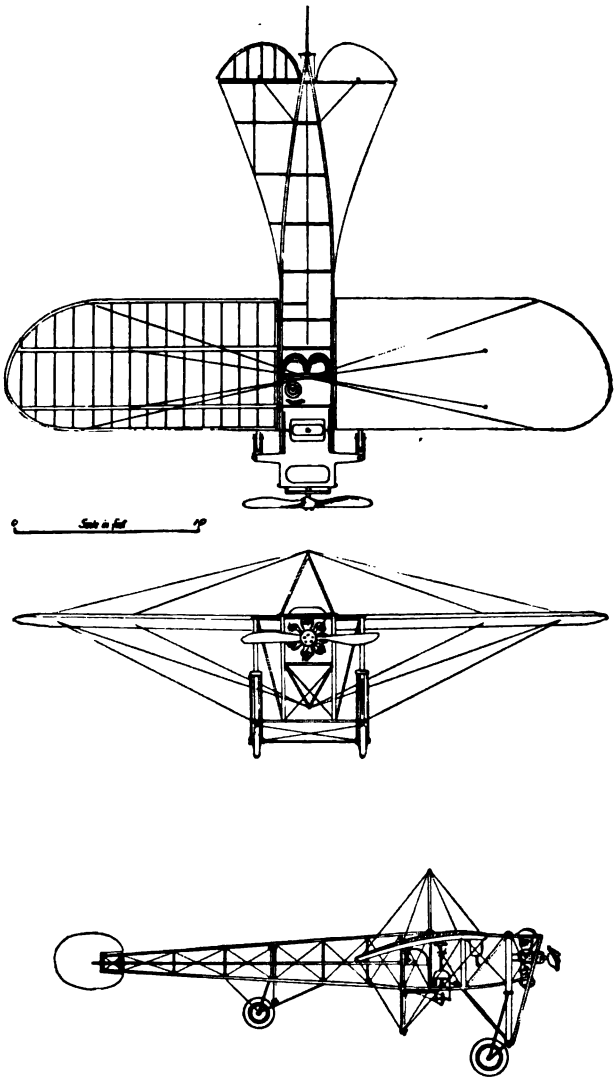
The Supporting Plane.—The plane is of the regulation Blériot type, fairly well arched (about 5 inches). The dihedral angle is very slight indeed. The halves are braced from the central *fuselage* and frame, in a slightly different manner than on the XI. *bis.* The plane has a spread of 36 feet. a chord of 7½ feet, and an area of 260 square feet.

MORANE WITH TWO PASSENGERS ON HIS BLERIOT XI 2 BIS
Note the framing, the fan-tail and the direction rudder at the rear.

The Elevation Rudder.—The elevation rudder consists of two semicircular flaps, trailing on the end of the dovetail-shaped keel. It is operated by the *cloche* exactly as in the XI. *bis.*

The Direction Rudder.—The small oval-shaped vertical surface at the rear is the direction rudder. It is controlled as in other Blériot types.

Transverse Control.—The transverse equilibrium is, as usual in this make, controlled by warping the planes about their base.



THE BLERIOT XI 2 BIS. PLAN, FRONT ELEVATION AND SIDE ELEVATION

Tail.—The curiously shaped tail on this machine gives it a remarkable bird-like appearance. It does not exert any considerable lift. The shape of the frame and tail on the No. XIV., flown by M. Blériot at Pau early in 1911, is quite different from the ordinary type. The frame itself narrows down, and gradually tapers into the form of the tail. The elevation rudder in this type is made of a single surface, and the direction rudder is in two halves, over and under the tail.

Propulsion.—A seven-cylinder Gnome motor drives a 7½-foot-diameter Regy propeller.

The *seats* for two are placed side by side in the frame between the two halves of the plane. In the very latest No. XIV. the seats are placed farther forward, and the frame in front built more in the form of a wind shield.

Mounting.—The mounting is on the usual Blériot wheel chassis at the front and a smaller wheel at the rear. The newest No. XIV. has a skid at the rear.

Weight, Speed, Loading and Aspect Ratio.—

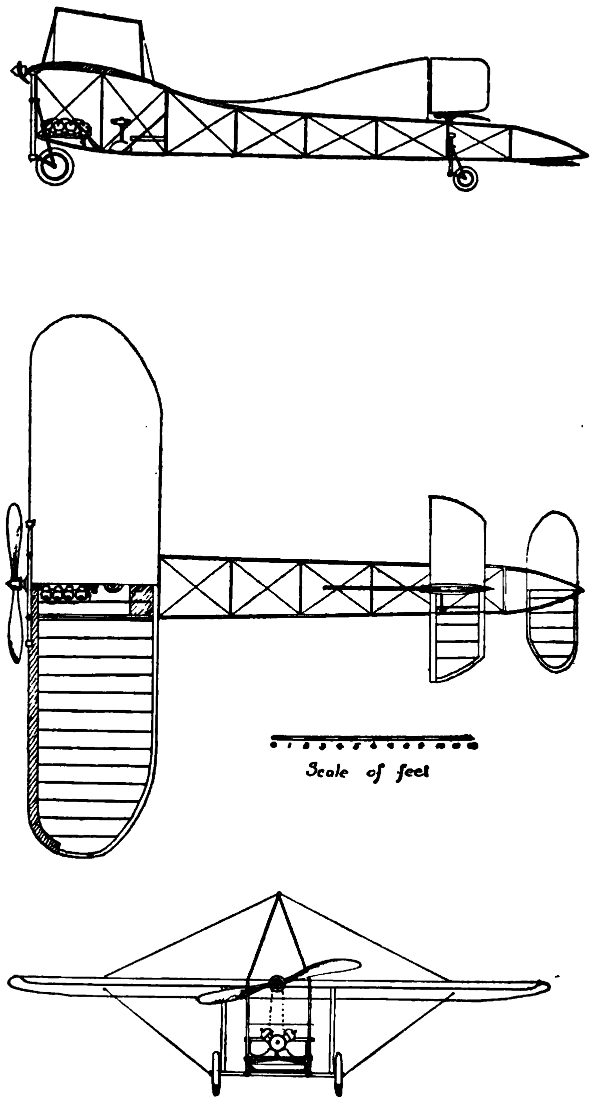
The total weight in flight is from 850 to 1,050 pounds. The speed is approximately 42 miles an hour; 21 pounds are lifted per horse-power, and 4.1 pounds carried per square foot of surface. The aspect ratio is 4.7 to 1.

References.—V. Quittner and A. Vorreiter, Zeit. für Flug. und Motorluft., November 26th, 1910: Aero, 1910, November 2nd, p. 350; Aircraft, December, 1910, p. 362; Flugsport, October 19th, 1910; L'Automobile, No. 338, 1910; Flight, 1910, October 22nd, p. 861; L'Aerophile, July 15th, 1910, p. 317.

4. THE BLÉRIOT XII. MONOPLANE

M. Blériot has also designed a passenger-carrying type of monoplane, the No. XII., which differs in structure from the No. XI. A type similar in form to the No. XII. is the small No. XIII., with which M. Blériot attained high speed at Rheims in 1909.

On June 12th, 1909, the first flight of an aeroplane carrying three passengers was accomplished by M. Blériot on his large No. XII. The machine at one time became popular, and more than ten aeroplanes of this type were flown.



The Bleriot XII. Side Elevation, Plan and Front Elevation

The Frame.—The long central frame of wood braced in every panel by cross wires is very deep at the front and tapers gracefully to a point at the rear.

GRAHAME-WHITE ON A BLERIOT XII.
The regulation *cloche* and foot-bar are clearly visible.

The Supporting Plane.—On the upper deck of the central frame at the front is placed the main plane, which is continuous and perfectly horizontal. The plane is braced by wires from the frame and its structure is similar to that of the Blériot No. XI. The spread is 30.2 feet, the depth is 7.6 feet, and the surface area is 228 square feet.

The Direction Rudder.—A single surface placed at the rear extremity of the vertical keel is used as the direction rudder. Its area is 9 square feet and it is operated by a foot lever as in No. XI.

The Elevation Rudder.—The elevation rudder consists of a single surface, placed at the extreme rear and 20 square feet in area. It is operated by the front and back motion of the *cloche.*

Transverse Control.—To preserve the lateral balance the main surface is warped inversely by the side-to-side motion of the *cloche,* exactly as in No. XI. A small surface under the seat also aids in lateral balancing.

Keels.—A horizontal keel of 21 square feet area is placed on the framework at the rear, but somewhat in front of the elevation rudder.

THE BLERIOT XII. IN FLIGHT.

Propulsion.—A 60 horse-power 8-cylinder E. N. V. motor is placed in the frame under the main plane. This motor drives by a chain transmission a single 2-bladed Chauviere propeller, the axis of which is placed on the edge of the main plane. This propeller is 8.8 feet in diameter and 9 feet pitch, and turns at 600 r.p.m.

The Seat or bench for three is placed in the frame under the main plane and back of the motor.

The Mounting is similar to that on No. XI.

Weight, Speed, Loading and Aspect Ratio.—

The total weight is from 1,150 to 1,300 pounds. The speed is 48 miles per hour; 21 pounds are lifted per horse-power and 5.3 pounds per square foot of surface. The aspect ratio is 4 to 1.

References.—Aerophile, v. 17, pp. 319, 488; SCI. AMERICAN SUP., v. 68, p. 136; Encyl. d'Av., v. 1, pp. 72, 92; Flug. Motor Tech., No. 20, p. 18; No. 22, p. 10; La Vie Auto, v. 9, p. 729; Locomocion Aerea, v. 1, p. 28; Aeronautics (Brit.), v. 2, p. 11'; L'Automobile, v. 7, p. 520; Genie Civil, v. 55, p. 344.

5. THE BLERIOT "AERO-BUS"

The four-seater Blériot "Aero-bus," first flown in February, 1911, at Pau, is a very marked departure from the usual Blériot types.

THE BLÉRIOT "AERO-BUS"

Eight passengers at the front and one at the rear about to start a flight. Le Martin, the pilot, has hold of the cloche.

The passengers sit under the main plane, as on the old No. XII, and as many as nine passengers have been carried with ease.

The accompanying photographs give an excellent idea of the framing and disposition of parts. The huge propeller, 10 feet in diameter, is driven by a 100 horse-power Gnome motor equipment.

The front elevation rudder and ailerons for transverse control bear distinct resemblance to the Farman biplanes. The practical

SIDE VIEW OF THE BLÉRIOT "AERO-BUS"

REAR VIEW OF THE BLÉRIOT "AERO-BUS"
The deep ribs are clearly shown in this photograph, as are also the ailerons.

elimination of cross-wires in the main framing and bracing of the planes on this type is a constructional detail that is worthy of note.

The spread of this machine is 43 feet and the surface area 430 square feet.

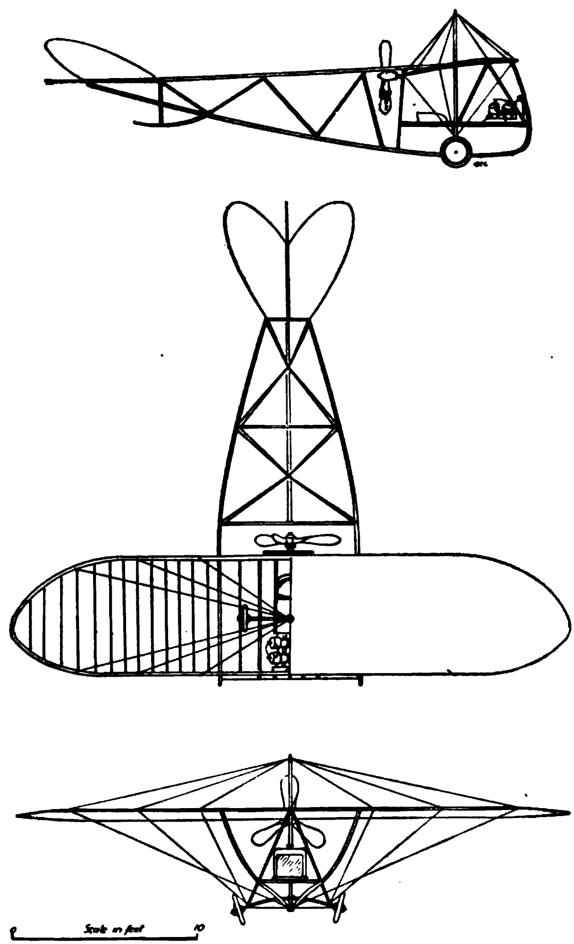
DETAIL VIEW OF THE BLÉRIOT "AERO-BUS"

The propeller, motor, and gasolene tank are grouped above and supported on strong framework.

The weight, empty, is 1,323 pounds, and the maximum "live load" carried is about 1,100 pounds; 24.25 pounds are lifted per horse-power and 5.63 pounds per square foot of surface.

6. THE DORNER MONOPLANE

The progress in Germany during 1910 was by no means restricted to imitating the French, as commonly supposed, but on the contrary many interesting and distinctive types of aeroplanes were evolved. Among these one of the most successful is the Dorner monoplane. This type resembles the v. Pischof more than any other. The weight carried per horse-power and the speed attained are high.



THE DORNER MONOPLANE. SIDE ELEVATION, PLAN AND FRONT ELEVATION

The Frame.—A triangular frame, wide and deep at the front, and the lower main member of which is projected out forward, serving as a skid, narrows to a point at the rear. The frame has not many cross wires, since inclined struts are used for giving the required rigidity. The entire length of the machine is 34 feet.

The Supporting Plane.—The main plane is perfectly horizontal and continuous as on the old Blériot XII. It is rounded at the ends and warpable. The spread is 38 feet, the chord 8¼ feet, and the surface area 280 square feet. The plane is braced from a central mast.

The Elevation Rudder.—The dove-like shaped tail, 60 square feet in area, is very flexible and is bent as on the Grade. The control is by means of a lever in the aviator's left hand, which when pushed forward bends the tail down and causes descent and when pulled back causes ascent.

The Direction Rudder.—A single flexible 16 square foot surface at the rear over the horizontal tail serves as the direction rudder. It is bent over to either side by means of a lever in the aviator's right hand.

Transverse Control.—The main surface is warped by the feet acting on pedals as on some of the latest French biplanes.

Tail.—The gracefulness and simplicity of the tail on the Dorner is quite in contrast to the complicated structure on the Pischof, the rudders themselves, when not in use, acting as a stabilizing *empennage.*

Propulsion.—The radiator and four-cylinder 22 horse-power water-cooled Dorner motor are placed in front of the two seats, all under the lower plane, as on the Blériot XII. and Pischof. The motor drives by chain a three-bladed wood and metal Dorner propeller, 8.4 feet diameter and 6½ feet pitch, at 670 r.p.m. The propeller is placed on a level with the entering edge of the main plane, at the rear.

Mounting.—The mounting is mainly on two rubber-tired wheels, and the main central skid at the front, with also a small skid at the rear.

Weight, Speed, Loading and Aspect Ratio.—

The speed is 50 miles an hour. The total weight is from 770 to 940 pounds; as much as 39 pounds are carried per horse-power, and 3 per square foot of surface. The aspect ratio is 4.6 to 1.

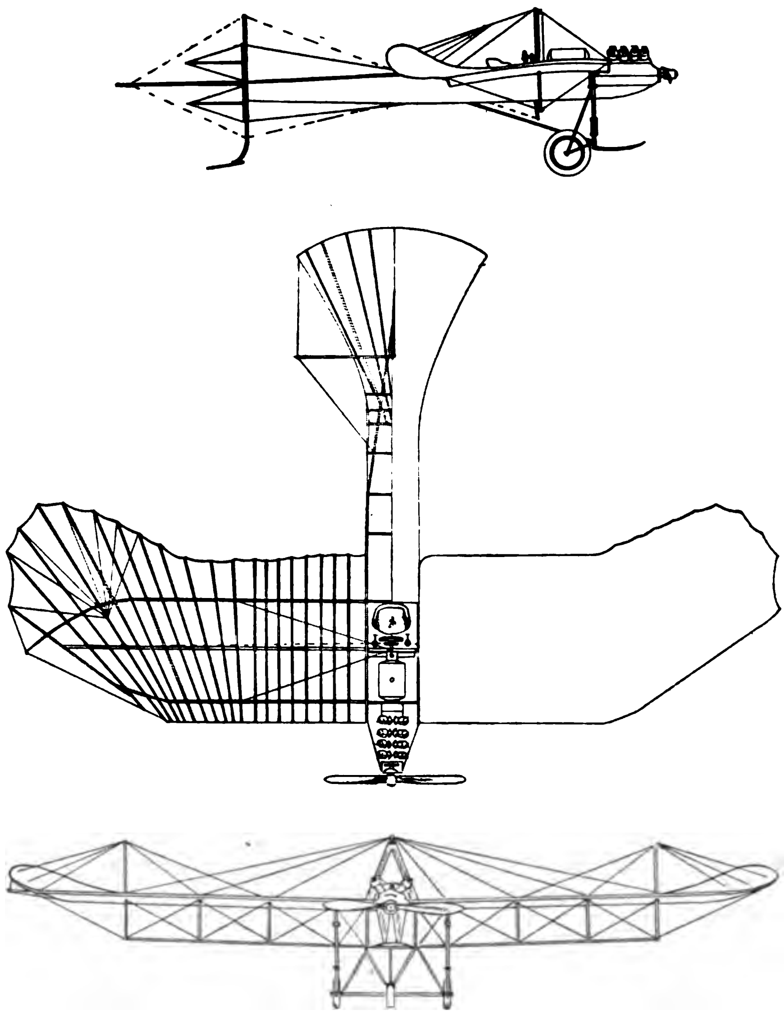
References.—Vorreiter, A. "Jahrbuch, 1911." p. 111; Zeit. für Luftschiff, No. 2, 1910; Zeit. für Flug. u Motorluft., September 24th, 1910; L'Aerophile, December 15th, 1910, p. 559.

7. THE ETRICH MONOPLANE

In Austria, the progress of aviation during the past few years has been closely bound up with the efforts of Igo Etrich and his associate, Herr Wels. Many years ago they began experimenting on lines laid down by the famous Austrian pioneer, Kress, whose work, more or less contemporaneous with Maxim, Langley, Renard, and Lilienthal, is well known. In 1906 they experimented successfully with a glider at Oberaltstadt, Bohemia. After having built many experimental machines at a time when motors were the cause of so much trouble to prospective aviators, Etrich and Wels finally evolved a somewhat successful type of monoplane in the early part of 1908. This machine, named by them the "Etrich-Wels III.," was substantially the same as the present-day type, excepting that it was equipped with a front elevation rudder which was later discarded.

During 1910, along with the progress elsewhere, Austria, represented by the Etrich IV. and the Warcholovski biplane (also designed by Etrich), jumped to the fore. Illner, one of the best Etrich monoplane pilots, flew from Steinfelde to Vienna across country on May 17, 1910; made an 80-kilometer cross-country flight on October 6th, 1910; flew from Vienna to Horn and back, a distance of 160 kilometers, four days later; and in the last week of the same month made a magnificent duration flight of over two hours. Aman has flown the Etrich well in France, and at Johannisthal (Berlin) the new Etrich-Rumpler made an excellent showing. The career of the Etrich, in fact, has been so brilliant that the Austrian Minister of War is said to have ordered twenty of this type for the army.

The Frame.—The frame of this machine is quite original. The main bracing of the plane consists of a single panel of



THE ETRICH MONOPLANE. SIDE ELEVATION, PLAN AND FRONT ELEVATION wire trussing and struts, very much as on a biplane, and placed laterally under the main plane. There is a central *fuselage,* and central struts as well as large struts at the outer end of each wing from which the plane is braced by a great number of wires. The entire construction reminds one of the old Lilienthal machines, and is in fact a distinct development of them, Etrich having the distinction of possessing one of these famous gliders. It is evident in the frame work and construction of the entire machine that the structure of a bird's wing has been very carefully studied, many features of the ribs, etc., resembling the feathers of a bird. Steel tubing and fine wood and cross-wire construction is used profusely throughout the frame.

The Supporting Plane.—The plane is shaped like a bird's wing and is tipped up at the rear ends, a device for stability that was suggested by Victor Tatin as well as by Lilienthal and that is also used on the Pischof monoplane. The halves are at a small dihedral angle as well. The sectional curvature is of the well-known Lilienthal bird-like form. The spread is 46 feet, the maximum chord is 9¾ feet, and the area 344 square feet. The ends have a depth of over 12 feet.

The Elevation Rudder.—At the rear is a very bird-like tail, the trailing edge of the horizontal *empennage* being moved up or down for ascent or descent. The control is by means of a column which is pivoted to move backward and forward, a forward push turning the tail down, etc. The rear horizontal *empennage* and tail is 14 feet long by 11 feet wide.

The Direction Rudder.—Two triangular surfaces are used, very much resembling the Antoinette. Rectangular surfaces are also sometimes used. They are operated by the two foot pedals. To turn to the right, for example, the left pedal is pressed down and the right up. This turns the rudder and at the same time turns the front wheels out to the left. The opposite control has also been employed occasionally, i. e., the right pedal pressed down for a turn to the right.

Transverse Control.—Warping of the wings is used for transverse control; the mechanism accomplishing it consists of wire and pulley connections to the steering wheel mounted on the control column. By turning the wheel clockwise, the left side is turned down and therefore lifts up, while the right is turned up and therefore sinks. The entire rear edge of the wing is flexible. The warping alone, however, is not supposed to be entirely responsible for the lateral movement. The rear turned-up ends are so curved that when warped up considerably. they form a pocket, very much like the blade of a turbine, which catches the air, and slows down that side. The other side then flies around and due to its higher speed and consequent increase of lift, cants up greatly. The result is that turns of such sharp curvature can be made, that the machine appears merely to pivot around the inside wing.

Tail.—The bird-like tail has vertical and horizontal *empennages.* The entire body is inclosed and shaped fusiform, adding still more to the bird-like appearance.

Propulsion.—Formerly a Clerget four-cylinder 50 horse-power motor, mounted at the front as on the Antoinette, was used, but of late both Rumpler eight-cylinder 55 horse-power and Austrian Daimler four-cylinder 65 horse-power motors have been used. The propeller is a Chauvière, 7.2 feet in diameter, 4 feet pitch, and rotates at 1,400 r.p.m.

The Mounting.—The mounting chassis resembles somewhat the Blériot. On the newest machines a large front skid has also been fitted. There is a small skid at the rear.

The *seat* is placed about in the center of the main plane, and is well protected from the exhaust, slip stream of the propeller, etc.

Speed, Weight, Loading and Aspect Ratio.—

The speed is 51 miles an hour. The total weight in flight is 1,100 pounds; 20 pounds are lifted per horse-power, and 3.2 pounds per square foot of surface. The aspect ratio is 4.72 to 1.

References.—Fachzeit. für Flug., October 16th, 1910, p. 15; November 13th, 1910, p. 23; L'Aerophile, March 1st, 1908, p. 80; June 15th, 1910, p. 271; December 15th, 1910, p. 559; Allge. Auto. Zeit., October 16th, 1910; Aircraft, November, 1910, p. 325; Flugsport, October 5th, 1910, p. 602; Flight, May 14th, 1910; Aero, November 30th, 1910, p. 428; La Conquete de l'Air, September 15th, 1910.

8. THE GRADE MONOPLANE

Herr Grade has the distinction of being one of the first German aviators to design and successfully fly an aeroplane. In the fall of 1909 he began flights on his interesting monoplane, and on October 30th, 1909, won the $10,000 Lanz prize for a German-built machine. Since then Herr Grade has made many excellent flights, and in the recent race meeting at Heliopolis he took a notable part. His machine is simple and flies easily. Many duplicates of this type have been sold. Among those who have flown this type are Rode, Treitschke and Plochman, who was later killed on an Aviatik biplane.

THE GRADE MONOPLANE IN FLIGHT

The Frame.—The frame consists essentially of a main metal tube chassis at the front, from which a long, thick piece, supporting the rudders is run out to the rear.

It is remarkable for its simplicity.

The Supporting Plane.—The main surface is made of Metzeler rubber fabric stretched over a bamboo frame. The surface is very flexible and the two ends are slightly turned up from the center. The curvature is almost the arc of a circle and the surface is very thin. The spread is 33 feet, the depth 8.5 feet, and the area 270 square feet.

The Direction Rudder.—The direction rudder consists of a single flexible surface of about 16 square feet area, carried at the rear and controlled by a lever operated by the aviator. The surface is not hinged, but is merely bent by the controlling wires in the desired way.

The Elevation Rudder.—The elevation rudder consists also of a single flexible surface placed at the rear. Its area is about 20 square feet and it is operated by a large lever universally pivoted on the frame above the aviator. To rise, this lever is pulled up, and to descend, it is pushed down, thus respectively bending up and bending down the rear horizontal surface.

Transverse Control.—The transverse control is effected by warping the main surfaces. This is accomplished through wires leading from the large lever previously referred to. Side to side motion of this lever warps the surfaces inversely. Thus if the machine tips down on the right, the lever is moved over to the left, thus raising the depressed side and depressing the elevated side.

Keels.—The tapering ends of both the direction and elevation rudders can be considered as keels. An additional vertical keel is placed in front, both above and below the main surface.

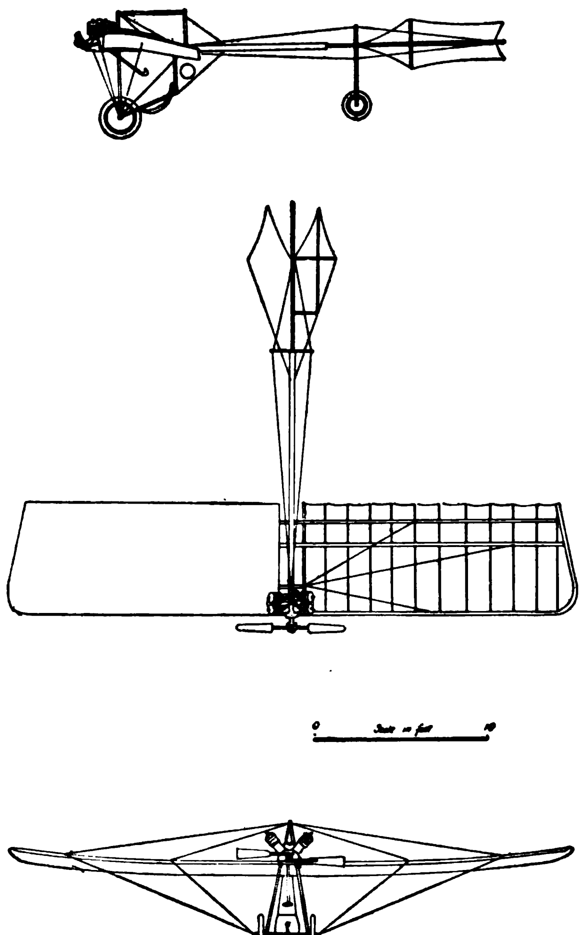
Propulsion.—A 4-cylinder 24 horse-power V-shaped motor is placed at the front edge of the plane. It drives direct at 1,000 r.p.m. a 2-bladed metal propeller 6 feet in diameter and 4 feet pitch. A Chauviere propeller has also recently been fitted.

The Seat is placed under the plane, and consists of a hammock-like piece of cloth which gives great comfort and little weight.

The Mounting is on two wheels at the front and one smaller one at the rear. There are no springs provided whatsoever on the chassis. The front wheels are fitted with a rake to bring the machine to a stop shortly after landing.

Weight, Speed, Loading and Aspect Ratio.—

The total weight is from 400 to 500 pounds. The speed is approximately 52 miles per hour; 17 pounds are lifted per horse-



THE GRADE MONOPLANE. SIDE ELEVATION, PLAN AND FRONT ELEVATION power and 2.0 pounds per square foot of surface. The aspect ratio is 3.9 to 1.

References.—SCI. AMERICAN, v. 101, p. 292; Aerophile, v. 17, pp. 439, 508; Zeit. für Luftschiff, v. 13, pp. 802, 957; Aero, v. 1, p. 405; Motor Car Jour., v. 2, p. 794; La Vie Auto, v. 9, p. 711; Zeit. Ver. Deut. Ing., v. 53, p. 1762.

9. THE HANRIOT MONOPLANE

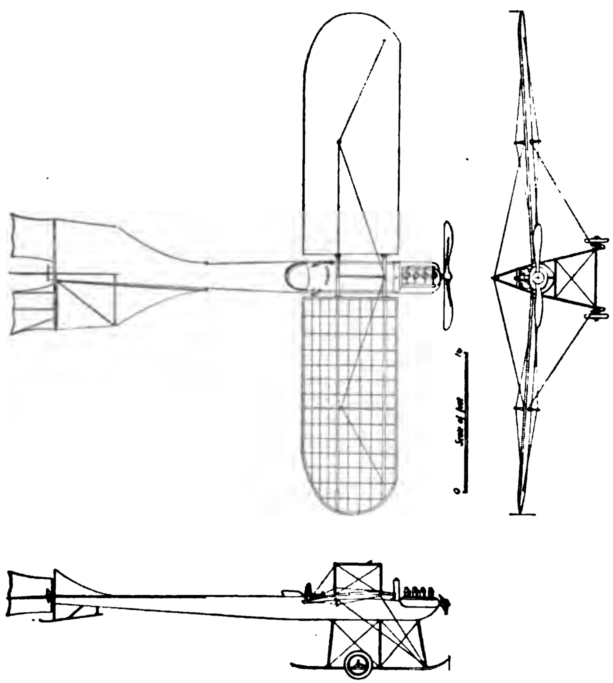
The Hanriot monoplane is a very recent type, with which excellent results have been obtained. It does not in any way depart radically from the regulation monoplane lines, but differs largely in structural details and dimensions. Vidart, Wagner, Marcel Hanriot, and Deletang, are some of the noted pilots of this exquisitely graceful machine.

CONTROL LEVER AND SEAT OF THE HANRIOT

A photograph of the Hanriot in flight is given in the frontispiece.

The Frame.—The general appearance of the Hanriot is very trim and shipshape. The central *fuselage* is built like a racing skull, and is very light and strong. This construction does away with the large amount of cross-wires, etc. The main spars for the planes are made of wood in three layers and are 3 inches deep and 1½ wide. The skids are fixed at the bottom of an A-type frame, the upper part of the A forming a triangular frame above the planes, to which the latter are fastened by stout wires.

The Supporting Plane.—The plane is divided in half. The halves are braced from the central frame, and set at a slight dihedral angle. Their corners are rounded. The section is medium-



PLAN AND ELEVATION OF THE HANRIOT ONE-PASSENGER MONOPLANE

ly thick and rather evenly curved, the greatest camber being near the center. The spread is 29½ feet, the depth 7 feet, and the surface area 183 square feet.

The Elevation Rudder.—Hinged to the rear of the horizontal tail are two flaps serving as the elevation rudder. All the rudders in the Hanriot are noteworthy for their small size. These rudders are operated by a lever in the aviator's right hand, which is pushed forward for descent and pulled in for ascent. The rudders are 2 feet deep.

The Direction Rudder.—A very small single surface, placed between the two elevation rudder flaps, is the direction rudder. It is operated by a foot bar, as on many of the French monoplanes.

Transverse Control.—Warping of the planes is used for transverse control. The rear spars are hinged, to permit of this. The lever controlling this is in the aviator's left hand, and when pulled to the right, elevates the left side of the machine. The control system is described in Chapter XIII.

Tail.—The horizontal *empennage*, non-lifting, resembles very much that on the Antoinette. A small triangular vertical *empennage* placed above the horizontal one is provided. The tail surface, however, is remarkable for its small size. The skiff-like frame does not come to a point on this type, although on the larger type it does. The total length is 26 feet. The tail is 8 feet wide, and in all 9 feet long.

Propulsion.—A four-cylinder 50 horse-power Clerget is usually provided and drives at 1,200 r.p.m.; a Chauvière propeller, 7.2 feet in diameter and 3.8 feet pitch, is placed about 3 feet in front of the main plane. An eight-cylinder E. N. V. 40 horse-power motor is also used.

The *Seat* is placed as in the Antoinette, and is very comfortable.

Mounting.—The mounting is mainly on two strong skids at the front supported by three uprights of the A-type frame work; the axles of the two wheels are carried on vertical guides, and are suspended by rubber springs anchored to the skids. There is a small skid at the rear.

Speed, Weight, Loading and Aspect Ratio.—

The speed is approximately 51 miles per hour. The total weight is 760 pounds; 15.2 pounds being lifted per horse-power, and 4.15 per unit of surface. The aspect ratio is 4.2 to 1.

There is a larger passenger-carrying type of this machine in which the spread is 43 feet and the surface 300 square feet. The total weight is 1,120 pounds, and the speed somewhat less than the small type.

References.—Aero, 1910, November 2nd, p. 350; October 12th, 1910, p. 291; Aeronautics (Brit.), September, 1910, p. 126; L'Aerophile, July 15th, 1910, p. 317; V. Quittner and A. Vorreiter, Zeit. für Flug. u Motor., November 26th, 1910; Flight, 1909, November 20th, p. 740; Flight, 1910, December 3rd, p. 986.

10. THE NIEUPORT MONOPLANE

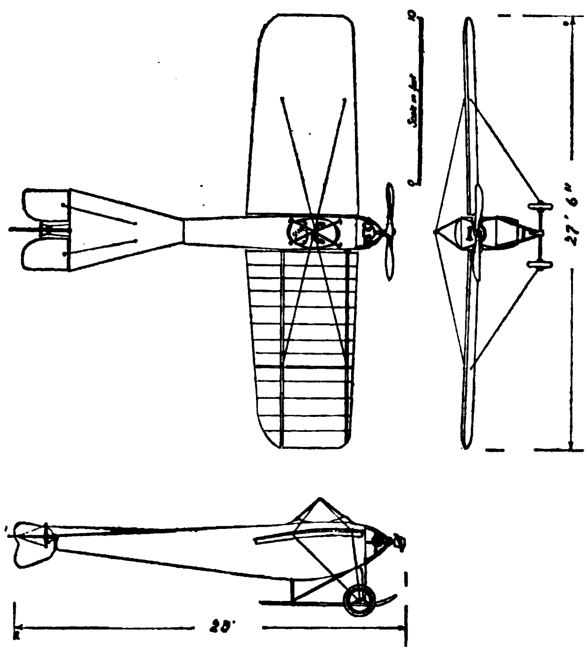
This extraordinary monoplane attracted a great deal of attention abroad during 1910 by its repeated flights at a speed of 52½ miles an hour with a small 18 to 20 horse-power engine. It is noted for the extreme simplicity of its design and the finish ex-

VIEW OF THE 1910 NIEUPORT MONOPLANE FROM BEHIND, SHOWING THE TAIL, FISH-LIKE BODY, AND WINGS

hibited in its structure. It resembles more the new R. E. P. monoplane than any other type, but is much smaller. An unusual feature is the almost complete manner in which the aviator is inclosed in the large fusiform hull. At Rheims in 1910 this type was flown by Niel, Nogues. and Nieuport.

The Frame.—The central framework is of wood, steel tube, and steel wire construction; and is completely inclosed except the seating space for the aviator.

The Supporting Plane.—The plane is very strongly built and is divided into two halves, each braced by only four cables from the central frame. The sectional curvature is quite flat and of even thickness. The head resistance of the framing, planes, and body, due principally to the reduction in the number of cross wires, is extremely low. The supporting plane has a spread of 27½ feet, a maximum chord of 6½ feet, and an area of 150 square feet.



PLAN AND ELEVATIONS OF THE ONE-PASSENGER 20-H. P. NIEUPORT MONOPLANE

The Elevation Rudder.—At the rear are the rudders, the two small horizontal surfaces serving to control the elevation. They are manipulated by the forward and back motion of the steering column as generally installed on French machines.

The Direction Rudder.—A small vertical surface at the rear between the two flaps of the elevation rudder, as on the Hanriot, is the direction rudder. It is operated by turning the steering wheel mounted on the control column. A biplane direction rudder was formerly used, but has been discarded.

Transverse Control.—The planes are warped in the usual manner, the control being by foot pedals as on the M. Farman and Voisin "Bordeaux," a type of control which is now coming into general use abroad.

Tail.—A bird-like tail, consisting of a tapering horizontal *empennage*, is provided. There is no vertical *empennage*, but the vertical sides of the large inclosed body fulfill this purpose. A horizontal lifting tail is provided on some of the types.

THE TAIL OF THE 1910 NIEUPORT MONOPLANE

On recent types, only one surface is used for steering; the elevation rudder consists of two small flaps and the keel shown here is discarded.

Propulsion.—One of the most interesting features of the Nieuport is the manner in which the two-cylinder Darracq 18 to 20 horse-power motor is mounted. The front spars of the frame project out beyond the inclosed body, and are joined together on either side by a steel joint. On the end of each cylinder is a pressed steel ring. These rings are fitted on the projecting steel joint end of the spars, and the motor there suspended. The motor drives direct a two-bladed Chauvière propeller, 6½ feet in diameter, 4 feet pitch, at 1,200 r.p.m.

The *Seat* is placed about on the center line of the planes, the aviator's head being flush with the top of the body.

The *Mounting* is mainly on two wheels, with a strong, springy axle, and a large skid at the center.

Speed, Weight, Loading and Aspect Ratio.—

The speed is 52½ miles an hour. The total weight is 670 pounds; 35 pounds are lifted per horse-power, and 4.5 pounds per square foot of surface. The aspect ratio is 4.23 to 1.

There is a two-passenger type of this machine, 34 feet spread, and having an area of 194 square feet. The total weight is about 860 pounds, and a Gnome 50 horse-power motor is used.

References.—Aero, 1910, November 2nd, p. 350; November 30th, p. 425; Flight, July 16th, 1910, p. 551; December 10th, 1910; Aerophile, July 15th, 1910, p. 317; Vorreiter, A. "Jahrbuch, 1911."

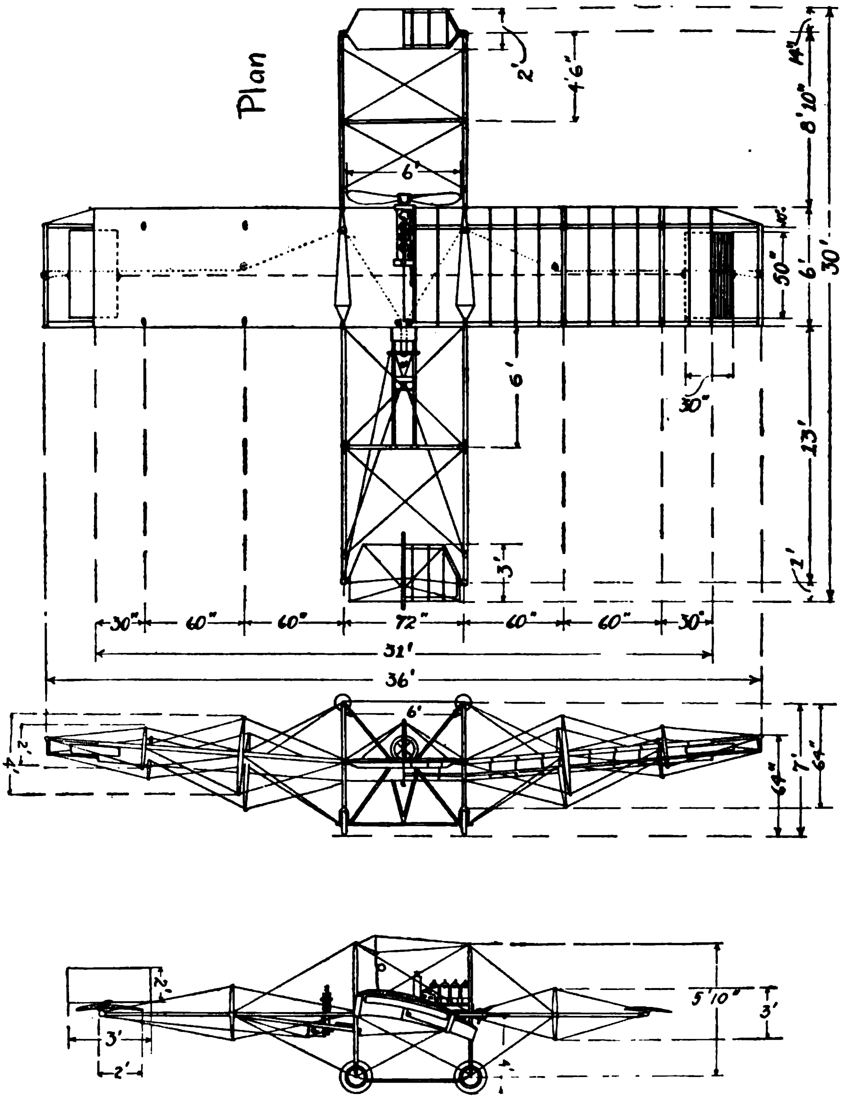
11. THE PFITZNER MONOPLANE

In the early part of January, 1910, the monoplane designed by Mr. A. L. Pfitzner and built at the Curtiss aeroplane factory at Hammondsport, N. Y., was completed and flown. The first flights were short, due largely to the inexperience of the aviator, Mr. Pfitzner, but the monoplane is considered by many to be a very promising type.

This aeroplane is a distinct departure from all other monoplanes in the placing of the motor, aviator, and rudders, and in the comparatively simple and efficient method of transverse control by sliding surfaces, applied here for the first time.

The Frame.—The framework is largely a combination of numerous king-post trusses with spruce compression members and wire tension members. The framework is open throughout, thus enabling quick inspection and easy repairs. The chassis at the center is mainly of steel tubing.

The Supporting Plane.—The main supporting plane at a 5-deg. dihedral angle consists of two main beams across which are placed spruce ribs. The surface is made of Baldwin vulcanized silk, of jet black color, tacked to the top of the ribs and laced to the frame. The curvature of the surface is slight and is designed



PLAN AND ELEVATIONS OF THE PFITZNER MONOPLANE for high speed. The spread is 31 feet, the depth 6 feet, and the surface area 186 square feet.

The Direction Rudder.—The direction rudder, a rectangular surface, is placed at the front and has an area of 6 square feet. It is operated by wires leading to the bracket underneath the controlling column. By turning this column to either side the aeroplane turns to that side.

The Elevation Rudder.—The elevation rudder consists of a single surface 17 square feet in area placed also at the front. It is operated by wires leading to the lever at the side of the con-

The Pfitzner Monoplane

A near view of the chassis, motor and controls.

trolling column. By moving this column forward or backward, the elevation rudder is caused to turn down or turn up respectively.

Transverse Control.—The framework of the main surface is carried out 30 inches on either end of the surface, and affords a place for the rail upon which the auxiliary sliding surfaces move. These sliding surfaces, or "equalizers" are each 12½ square feet in area, and when normal project 15 inches beyond the end of the surface on either side. They are connected by a wire to each other, and a long cable running to each end through a pulley connects them to the steering wheel. The control is then as follows: If the right end of the aeroplane is tipped down, the wheel supported on the controlling column is turned away from the lowered side. This causes the equalizer on the raised end to be pulled in under the main surface, while at the same time the one on the other end is pulled out. This action merely decreases the supporting surface on the raised end and increases that on the lowered end, thus righting the machine.

Keels.—A horizontal surface placed at the rear acts as a longitudinal stabilizer. It is 10.5 square feet in area, and is fixed firmly to the supporting framework, 10 feet in the rear of the main surface.

Propulsion.—A 25 horse-power Curtiss 4-cylinder motor is placed on the framework above the plane and at the rear of it. The motor drives direct a 2-bladed wooden propeller 6 feet in diameter and 4.5 feet pitch at 1,200 r.p.m. The propeller is of original design and said to be very efficient.

The Seat for the aviator is placed out in front of the main plane and directly on the center line.

The Mounting is on four small rubber-tired wheels, placed at the lower ends of the four main vertical posts of the chassis. The wheels are not mounted on springs. They are spaced by steel tubing and are fitted with brakes.

Weight, Speed, Loading and Aspect Ratio.—

The total weight in flight is from 560 to 600 pounds. The speed is estimated at 42 miles per hour; 24 pounds are lifted per horse-power, and 3.2 pounds carried per square foot of surface. The aspect ratio is 5.17 to 1.

References.—Aeronautics, v. 6, p. 53, February, 1910; v. 6, p. 82, March, 1910.

12. THE PISCHOF MONOPLANE (AUSTRIAN)

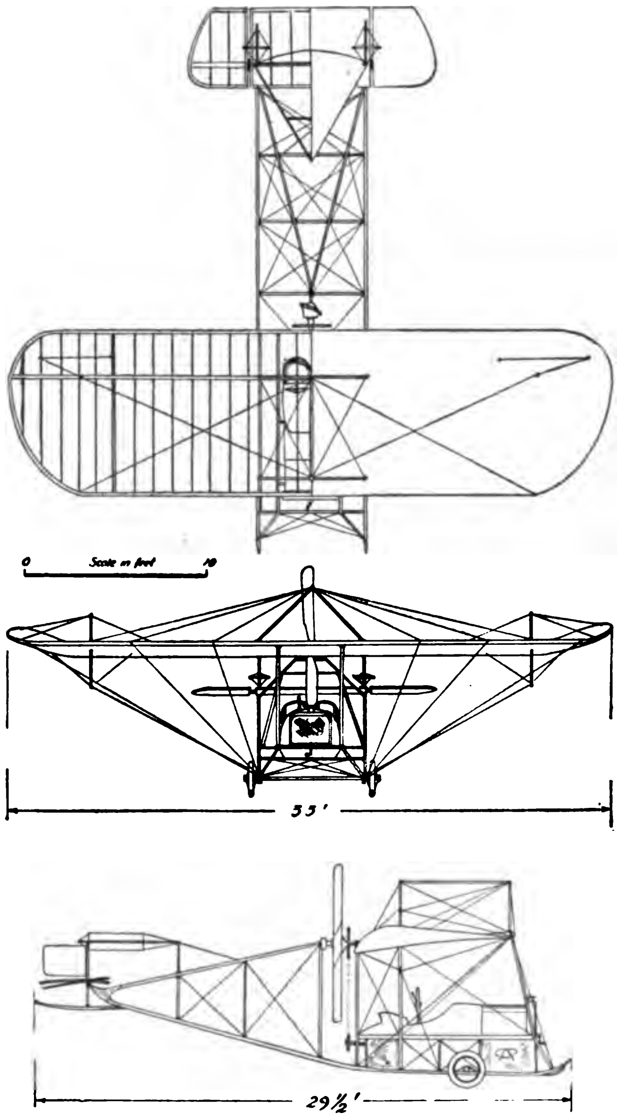
This monoplane is a distinct departure from usual practice, and is particularly notable for the position of its propeller, its low center of gravity, the upturned ends of the plane, and the provision of a clutch enabling the aviator to start the motor, step into the machine, and then start the propeller. Many biplanes and monoplanes were built by M. Pischof in 1907 and 1908. The present type, with its chassis like a motor car, has been flown very well this summer, and certainly incorporates many practical and far-sighted innovations. Despite its low center of gravity, it flies easily around corners. This type is manufactured by the Autoplan-Werke in Vienna, as is also the Warchalowski biplane.

THE PISCHOF MONOPLANE

A view of the body, showing the automobile-like radiator and motor casing, the crank and the propeller which is governed by a clutch.

The Frame.—The wooden cross-wired frame is everywhere painted with an aluminum mixture, as were the Wright machines. The joints are very strong, and the lower members are continued out in front to form skids. A great many cross-wires and bracing wires are used, considerably complicating the structure.

The Supporting Plane.—The main surface is perfectly straight in front. The rear edges are turned up slightly, as on the Etrich IV. It is claimed that this adds greatly to the stability. The plane is braced from the central frame, and its trailing edge is



PLAN AND ELEVATIONS OF THE PISCHOF MONOPLANE warpable. The spread is 36 feet, the chord 9 feet, and the area 290 square feet.

The Elevation Rudder.—A Blériot XI. type elevation rudder is carried at the rear. The central portion is rigid, and the two outer portions movable. They are manipulated by the forward and back movement of a large lever in front of the aviator, forward for descent, etc.

THE PISCHOF MONOPLANE IN FLIGHT

The Direction Rudder.—Two identical surfaces at the rear above the elevator are the direction rudders. They are moved by a foot lever and wires.

Transverse Control.—The transverse control is obtained by warping the rear of the planes. This is done by the side-to-side motion of the large control lever.

Tail.—In addition to the fixed surface of the elevation rudder, there is also a triangular surface at the rear. Both exert considerable lift. Over and under the triangular surfaces are small vertical keels. At the front two sections of the chassis frame are inclosed, to form vertical keels, which in turning help to avoid the effect of the low center of gravity.

Propulsion.—The propelling system of the Pischof is one of its most radical features. The motor is placed in front under the planes with a radiator in front of it and two seats in back of it, exactly as on an automobile. The motor of 60 to 70 horse-power drives by a shaft, clutch, and chains, the single variable pitch Normale 8½-foot diameter propeller, placed at the center and flush with the rear of the plane. Here for the first time is a practical and successful means of providing a monoplane with a propeller at the rear instead of at the front. Gnome, E. N. V., and Daimler motors have been used.

Seats.—The position of the aviator's seat and that of his passenger is very practical, and enables a clear view in every direction, as well as being away from the propeller slip stream, etc.

The Mounting.—The mounting is on two wheels at the front fitted with springs and two small wheels at the rear. The long skids at the front, really forming part of the frame, are fitted with small supplementary skids.

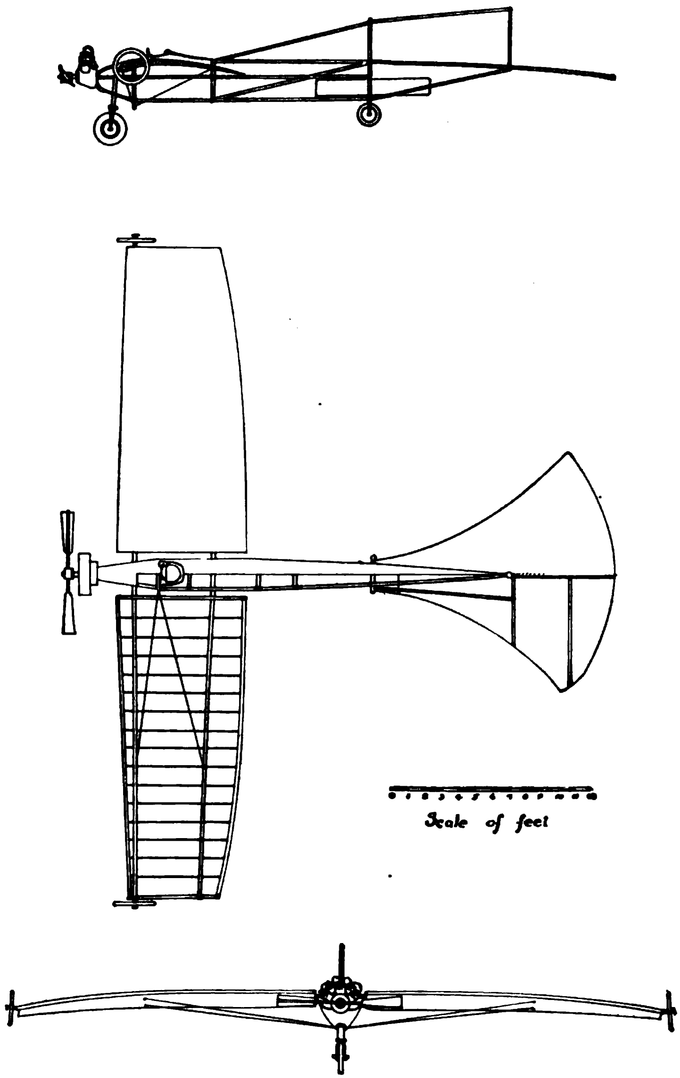
Speed, Weight, Loading and Aspect Ratio.—

The speed is high for so large a machine, 53 miles per hour often being attained. The total weight in flight is from 910 to 1,060 pounds; 17½ pounds are lifted per horse-power, and 3.65 per square foot of surface. The aspect ratio is 4 to 1.

References.—Flight, July 16th, 1910, p. 551; November 19th, 1910, p. 948; Aircraft, November, 1910, p. 328; L'Aero, November 17th, 1910; Rv. de l'Aviation, December, 1907; August 15th, 1908; November 15th, 1908; L'Aerophile, November, 1907, p. 328; Vorreiter, A. "Jahrbuch, 1911."

13. THE R. E. P. MONOPLANE (1909)

The old R. E. P. monoplane was considered by many to be one of the most perfect types of aeroplanes. Great finish was exhibited in its construction and form, but due probably to motor troubles it never was flown for any great length of time. M. Pelterie, the designer, is one of the foremost aviation scientists abroad,



THE R. E. P. 1909 MONOPLANE

Side elevation plan and front elevation, showing the negative dihedral angle and wheels at ends of plane.

and previous to his experience with this machine he conducted a series of gliding experiments of great interest.

The Frame.—The central frame, somewhat similar in shape to a bird's body, was made largely of steel tubing, and was quite short. All exposed parts were covered with Continental cloth.

The Supporting Plane.—The main surface was particularly strong and solid, and was made of steel tubing carrying wooden ribs covered with Continental cloth. The curvature was very similar to that of a bird's wing, and transversely the surface curved downward dihedrally from the center. There was very little bracing necessary. The spread was 35 feet, the depth 6.1 feet, and the area 214 square feet.

The Direction Rudder.—The rudder for steering from side to side consisted of a vertical rectangular surface of 8 square feet area, placed below the central frame at the rear. It was operated by the side-to-side motion of the lever at the aviator's right hand. To turn to any side the lever was inclined to that side.

The *Elevation Control.*—There was no elevation rudder in the 1909 Pelterie monoplane, the elevation of the machine being regulated by changing the incidence of the main plane itself. To ascend, for example, the aviator pulled the lever in his left hand toward him. This increased the incident angle of the plane and the consequent increase of lift caused the machine to rise.

Transverse Control.—Each half of the main plane was warpable about its base, and transverse equilibrium was obtained by an inverse warping of the plane. The side-to-side motion of the left-hand lever controlled the warping. If the machine was tipped down on the right end the lever was moved to the left and the machine brought back to an even keel. In turning to either side both the left-hand lever controlling the warping and the right-hand lever controlling the direction rudder were simultaneously moved to that side. This was a very effective controlling system.

Keels.—Vertical and horizontal keels, consisting of gradually tapering surfaces, were fixed to the frame and aided in preserving stability. The rear horizontal keel, shaped like a bird's tail, had an area of 20 square feet.

Propulsion.—A 7-cylinder 35 horse-power R. E. P. motor, placed at the front, drove direct a four-bladed aluminum and steel propeller at 900 r.p.m. The diameter of the propeller was 6.6 feet, and the pitch 5 feet.

The Seat was placed in the frame, and protected on all sides. The aviator's shoulders were flush with the surface.

The Mounting was mainly on a large single wheel with an oleo-pneumatic spring in the center at the front and a smaller one in the same center line at the rear. When first starting the aeroplane was inclined, resting on one end of the plane, on each end of which a wheel was placed.

Weight, Speed, Loading and Aspect Ratio.—

The total weight was from 900 to 970 pounds. The speed was 39 miles per hour; 27 pounds were lifted per horse-power, and 4.4 pounds carried per square foot of surface. The aspect ratio was 5.75 to 1.

References.—Soc. des Ing. Civ., v. 2 (1908), p. 13; Boll. Soc. Aer. Ital., v. 6, pp. 67, 288; Aerophile, v. 15, p. 331; v. 16, p. 226; v. 17, p. 33; Flight, v. 1, pp. 19, 360; Aeronautical Jour., v. 13, p. 64; Zeit. für Luftschiff, v. 12, p. 458; Aeronautics, v. 4, p. 21; La France Aerienne, v. 14, Nos. 7, 9; Zeit. Ver. Deut. Ing., v. 53, p. 1760; Genie Civil, v. 55, p. 346.

14. THE R. E. P. 1911 (ONE-SEAT)

The newest product of M. Esnault-Pelterie differs radically from the older type in the method of elevation control and in the construction of the tail as well as in propeller, motor, etc. This type is built in two sizes (one or two seater) and preserves in great measure the graceful lines of its predecessors. In view of the recent excellent flights of Laurens and Bournique, with and without passenger, and because of its high speed, reliability and stability the scarlet bird-like R. E. P. has at last taken its rank among the very best flying machines of the day. Bournique on the small R. E. P. flies at 60 miles an hour, and only recently M. and Mme. Laurens established a passenger speed record. Bournique on December 31st, 1910, in competition for the Michelin cup, flew this type 331 miles.

The Frame.—The splendid non-soldered steel-tube construction of the frame gives great strength and durability. In the minutest details the R. E. P. exhibits excellent workmanship. All joints are welded.

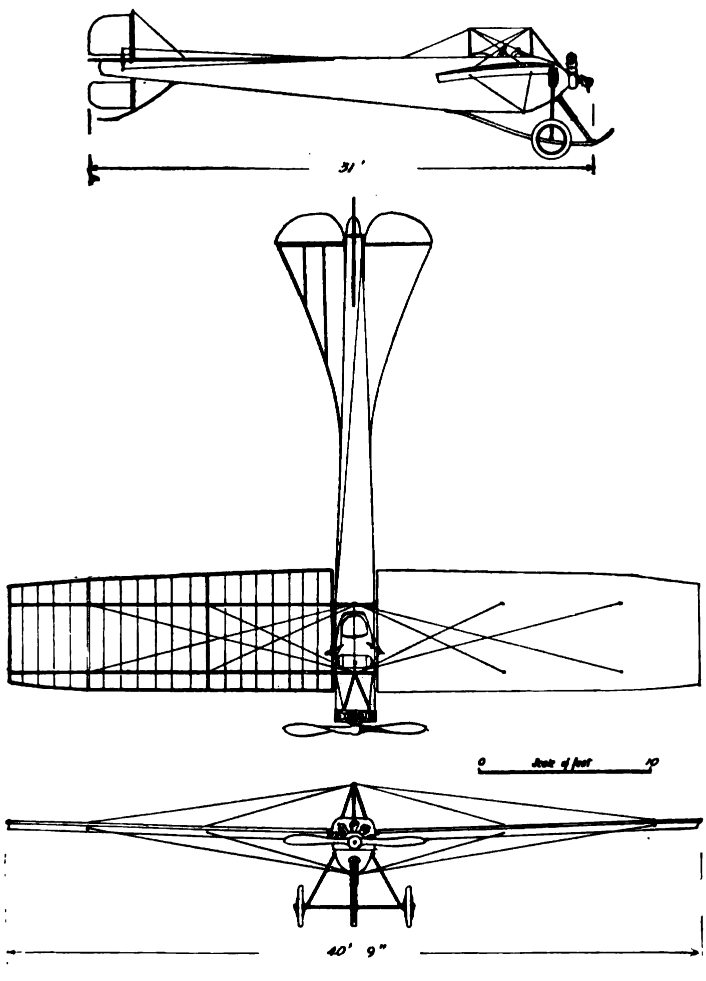
The Supporting Plane.—The plane is similar in shape and structure to the old R. E. P. It is fixed to the central frame by

Courtesy of "Flight."

THE FRONT OF THE R. E. P. (1911)

Showing the landing chassis, motor, propeller and part of body. The wheel axles are pivoted to the central skid. The skid itself is fitted with a strong spring.

four cables, and its incidence cannot be changed as formerly. It is, however, warpable. The two halves are set at an upward dihedral angle, and not turned down as on the old type. The material used is a red vulcanized cotton fabric. The cables used



SIDE ELEVATION, PLAN AND FRONT ELEVATION OF THE 1911 ONE-SEAT R. E. P.

to support the frame are more numerous, and the plane is braced both above and below. The frame consists of two main steel laterals with ribs having an I-section. The spread is 42 feet, the mean chord 6½ feet, and the area 270 square feet.

The Elevation Rudder.—The elevation rudder consists of two flaps on the end of the horizontal tail. The alteration of the incidence of the main planes to control elevation is entirely discarded in this type. The elevators are controlled by the to-and-fro motion of the left-hand lever.

THE 1911 R. E. P. AS SEEN FROM BEHIND, SHOWING THE REAR TAIL AND RUDDERS, AND AT THE FRONT, THE MAIN PLANE

The Direction Rudder.—Two small planes at the rear, moved jointly, serve as the direction rudder. They are operated either by the side-to-side motion of the right-hand lever, as on the former type, or by an ordinary foot pedal.

Transverse Control.—The widely used warping method of transverse control is here employed. The warping is controlled by the side-to-side motion of the left-hand lever.

Tail.—The rear is greatly altered in form. The vertical *empennage* is very much smaller, as is also the horizontal non-lifting tail. The entire tail can readily be dismounted.

Propulsion.—A five-cylinder 55 horse-power R. E. P. motor is installed at the front, and the recent success of this type is largely due to the great improvements in this motor. The two-bladed 8¼-foot wooden Regy propeller is driven direct at a speed varying between 500 and 1,250 r.p.m. The four-bladed propeller formerly used is discarded.

The Mounting.—The mounting is altogether different from the old type, and is very simple. The single central wheel is abandoned, and in its stead is a large skid fitted by a springy telescoping steel tube to the main *fuselage.* A steel-tube frame and axle

THE RUDDERS AND TAIL OF THE 1911 R. E. P.

also support two rubber-tired wheels, one on either side of this skid, fitted with rubber rope springs. A small skid is fixed at the rear. No wheels are placed on the ends of the plane.

The *Seat* is placed as formerly, and is well protected.

Speed, Weight, Loading and Aspect Ratio.—

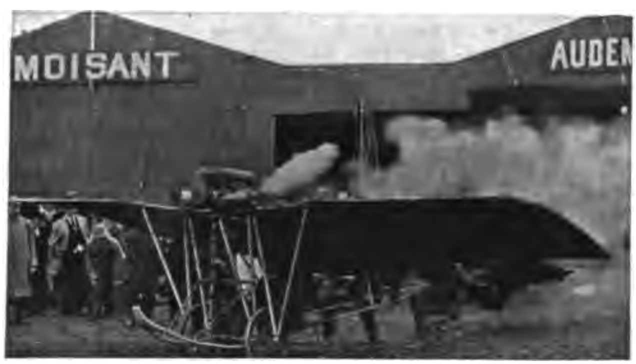
The speed is almost 60 miles an hour. The total weight is from 1,180 to 1,240 pounds; 22.5 pounds are carried per horsepower, and 4.6 per square foot of surface. The aspect ratio is 6.5 to 1.

References.—"Neve Flugzeuge in Paris," Zeit. für Flug. u Motor, November 26th, 1910; Flight, 1910, October 22nd, p. 862; October, 29th, p. 880; L'Aero, 1910, October 28th; December 1st; Aero, 1910, October 26th; November 2nd, p. 350; November 16th; Flugsport, October 19th, 1910.

15. THE SANTOS-DUMONT MONOPLANE

The first sustained flight of a motor aeroplane in Europe was made by M. Santos-Dumont on November 12th, 1906, in a biplane of his design. In 1907 he began work on a monoplane, and after much alteration, has finally evolved the highly successful and interesting little monoplane, the "Demoiselle." This is the smallest aeroplane in use to-day. Many machines of this type are being flown abroad, and their simplicity renders them quite popular.

The Frame.—The frame, which narrows toward the rear, is made of bamboo and steel joints, with several members of metal tubing.

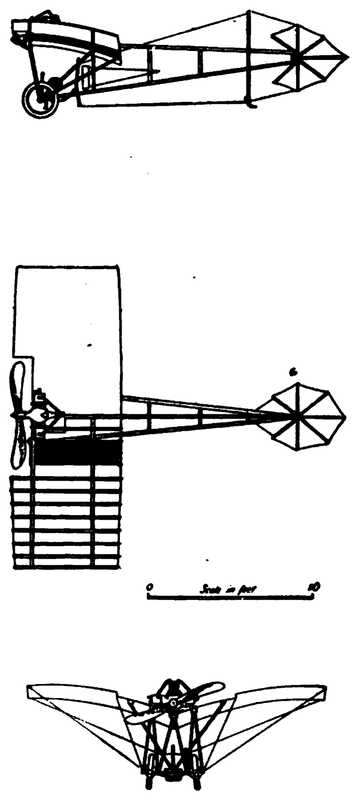


AUDEMARS ON HIS "DEMOISELLE" ABOUT TO START ON A SPEEDY LAP AT BELMONT PARK

The propeller, at the front, is rotating so fast that only the hub is visible. Note how the smoke is blown back by the propeller draught.

The Supporting Plane.—The supporting plane has both sides slightly turned up from the center, and consists of a double layer of silk stretched very tightly over bamboo ribs. The plane is braced by wires to the central frame. The curvature is approximately the arc of a circle. The spread is 18 feet, the depth 6.56 feet and the area 113 square feet.

The Direction Rudder and the Elevation Rudder.—The two rudders are combined at the rear into two fan-shaped surfaces, one vertical and the other horizontal. They are pivoted on a single universal joint. The elevation rudder is 21 square feet in area, while the direction rudder is somewhat less. A lever at the aviator's right hand controls the movement of the elevation rudder,



SIDE ELEVATION, PLAN AND FRONT ELEVATION OF THE SANTOS DUMONT MONOPLANE "DEMOISELLE"

while a small steering wheel at the aviator's left hand controls the direction rudder. To rise the tail is moved up, while to turn to the right it is moved to the right.

Transverse Control.—Transverse control is effected in the Santos-Dumont by the warping of the main planes. This action is governed by a lever at the back of the aviator, and which fits into a socket sewed on his coat. If the aeroplane should suddenly

SANTOS DUMONT TRAVELLING ACROSS COUNTRY

tip up on the left, then the aviator, by moving quickly to the left, pulls down and increases the angle of incidence of the right side of the plane. The ribs of the plane are flexible in this machine.

Keels.—There are no keels in the Santos-Dumont monoplane.

Propulsion.—A 30 horse-power water-cooled Darracq 2-cylinder motor placed on the top of the plane at the front drives direct a 2-bladed Chauviere wooden propeller 6.9 feet diameter and 6 feet pitch at 1,400 revolutions per minute. Clement-Bayard and Panhard motors are also used on this type of monoplane.

The Seat is a strip of canvas placed across the frame below the main plane.

The Mounting consists of two wheels at the front and a skid at the rear. No springs are provided on the wheels.

Weight, Speed, Loading and Aspect Ratio.—

The total weight is from 330 to 370 pounds; the speed is 55 miles per hour; 12 pounds are lifted per horse-power and 3.1 pounds per square foot of surface. The aspect ratio is 3 to 1.

References.—Flight, v. 1, p. 603; Sci. American Sup., v. 68, p. 317; Sci. American, v. 97, p. 445; v. 99, p. 433; Aerophile, v. 15, p. 313; v. 16, p. 468; v. 17, pp. 435, 488; L'Aviation Ill., No. 34, p. 3; La France Aerienne, v. 14, p. 608; Omnia, No. 200, p. 281; Encyl. d'Av., v. 1, p. 126; Vorreiter, A., "Motor Flugapparate"; Zeit. Ver. Deut. Ing., v. 53, p. 1762; Genie Civil, v. 55, p. 466.

16. THE SOMMER MONOPLANE

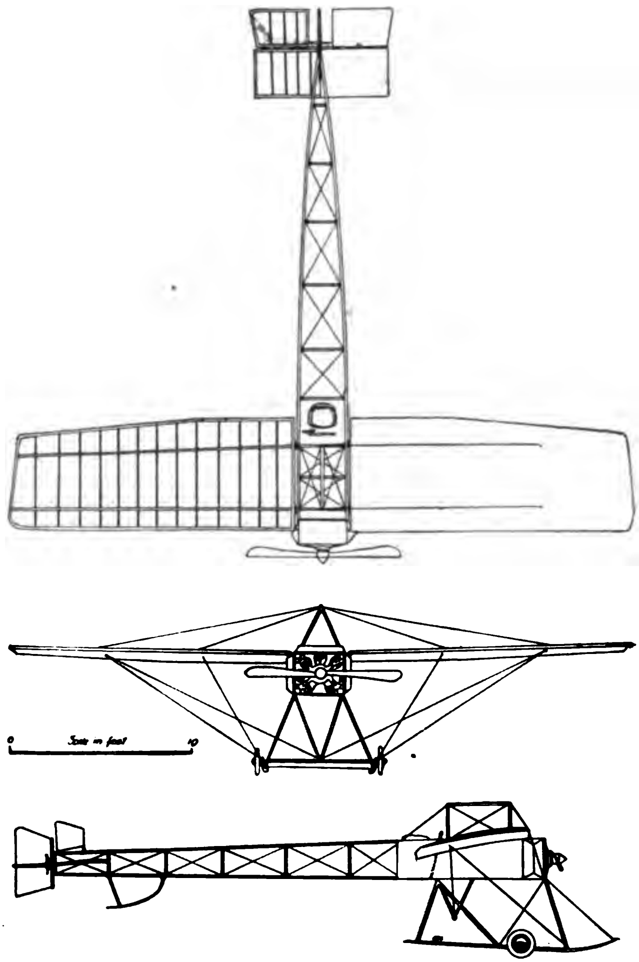
M. Roger Sommer has recently brought out a monoplane which follows regulation lines, but is exceptionally strong. In this machine M. Sommer at Douzy has already made many creditable flights. The general aspect reminds one of a Blériot *fuselage* mounted on a biplane chassis.

The Frame.—The central frame *fuselage* is of the ordinary wood and wire construction covered for some distance under the wings. There is a Blériot XI. type frame above the plane to which it is braced.

The Supporting Plane.—The plane is divided into two halves set at a dihedral angle, braced by wires to the central frame, and strongly resembling the Blériot. The spread is 34½ feet, the chord 5½ feet, and the area 183 square feet. The main transverse member of the frame of the planes is a huge I-beam of wood.

The Elevation Rudder.—Two flaps fitted on the trailing end of a weight-carrying horizontal *empennage*, form the elevation rudder. They are controlled by a large lever as on the Sommer biplane. All control wires are duplicate

The Direction Rudder.—A single surface placed between the two flaps of the elevator serves as the direction rudder, and is moved by means of a foot pedal in the usual manner.



THE SOMMER MONOPLANE

Note the splendid landing chassis.

Transverse Control.—The planes are warped by means of the side-to-side motion of the large control lever, a movement to the left causing the right side to ascend.

Propulsion.—A 50 horse-power seven-cylinder Gnome motor is placed at the front and almost completely boxed in. It drives direct a two-bladed "Rapid" propeller, 8.3 feet in diameter, at 1,200 r.p.m.

Mounting.—The mounting is on two main skids supported by framework to the *fuselage,* and across which is fitted an axle with rubber springs and carrying a rubber-tired wheel at each end. At the rear is a cane skid.

Speed, Weight, Loading and Aspect Ratio.—

The speed is about 54 miles an hour. The total weight is 690 pounds, making the pounds carried per horse-power 14, and the pounds per unit surface 3.8. The aspect ratio is 6.2 to 1.

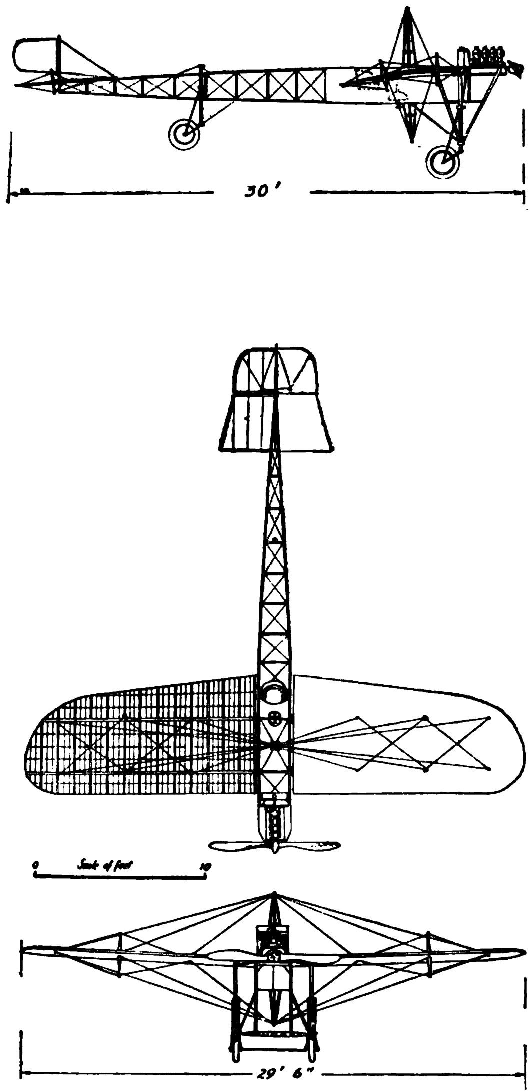
References.—Aero, 1910, October 26th, November 2nd; Zeit. für Flug. und Motor, 1910, November 12th, p. 278; November 26th.

Courtesy of "Flight"

THE TELLIER MONOPLANE

17. THE TELLIER MONOPLANE

The Tellier monoplane flown by Dubonnet was so manageable that he obtained his pilot's license on his fourth outing, and occupied the commissioners only half an hour. Shortly thereafter



SIDE ELEVATION, PLAN AND FRONT ELEVATION OF THE TELLIER MONOPLANE he made a wonderful flight over Paris, and since then Dubonnet as well as others have shown the Tellier to be a peculiarly strong and reliable machine. It is very much like the other French monoplanes in general aspect, but differs considerably in the shape of the tail, frame-work, etc.

The Frame.—The frame is a very light and strong wood and cross-wire construction, and resembles the Blériot frame. At the center between the two halves of the plane is a large frame mast, and this, with the struts out on the plane, makes the bracing very similar to the Antoinette.

The Supporting Plane.—The plane is divided into two halves set at a small dihedral angle, and more solidly built up with wooden ribs and spars than is customary. The planes are therefore exceptionally strong. They are mediumly curved, and about 3 inches thick at the center. The planes are very strongly braced, and are covered on both sides. The spread is 29½ feet, the chord (maximum), 7½ feet, and the surface area, 220 square feet. A two-passenger type of this machine is built, in which the spread is 38¾ feet, the chord 8 feet, and the area 280 square feet.

The Elevation Rudder.—At the rear is a trapezoidal-shaped horizontal keel, and hinged to the rear of this is the single-surface elevation rudder. Several different types of control have been used, the most common being a Blériot *cloche*, on which the wheel moves. To-and-fro motion is for elevation or depression.

The Direction Rudder.—The single direction rudder at the rear is placed above the elevation rudder. It is operated by a steering wheel mounted on the Blériot type *cloche*, and turned as usual, clockwise for a turn to right.

Transverse Control.—The planes are warped by the side-to-side motion of the *cloche*, as usually done.

Tail.—Beside the horizontal tail surface already mentioned, there is a small triangular vertical keel just in front of the direction rudder.

Propulsion.—On the small type a four-cylinder Panhard 45 horse-power motor is used, and drives direct a two-bladed wooden propeller 8 feet in diameter. On some of the larger types a six-cylinder 60 horse-power Panhard is used. R. E. P. motors are also fitted.

Mounting.—This machine is mounted on three wheels, two at the front and one smaller one at the rear. The two at the front are mounted on springs and on an elaborate chassis.

The *Seat* is comfortably placed near the rear of the main surface.

Speed, Weight, Loading and Aspect Ratio.—

The speed is 53 miles an hour. The total weight is 850 to 900 pounds; 19 pounds are lifted per horse-power, and 4 per square foot of surface. The aspect ratio is 4.2 to 1.

References.—Aero, 1910, October 26th; November 2nd, p. 350; November 9th, p. 364; Flight, 1910, August 6th, p. 621; September 17th p. 754; p. 759; October 29th, p. 882; December 3rd, p. 991; L'Aerophile, 1910, March 22nd, p. 151; July 15th, p. 317.

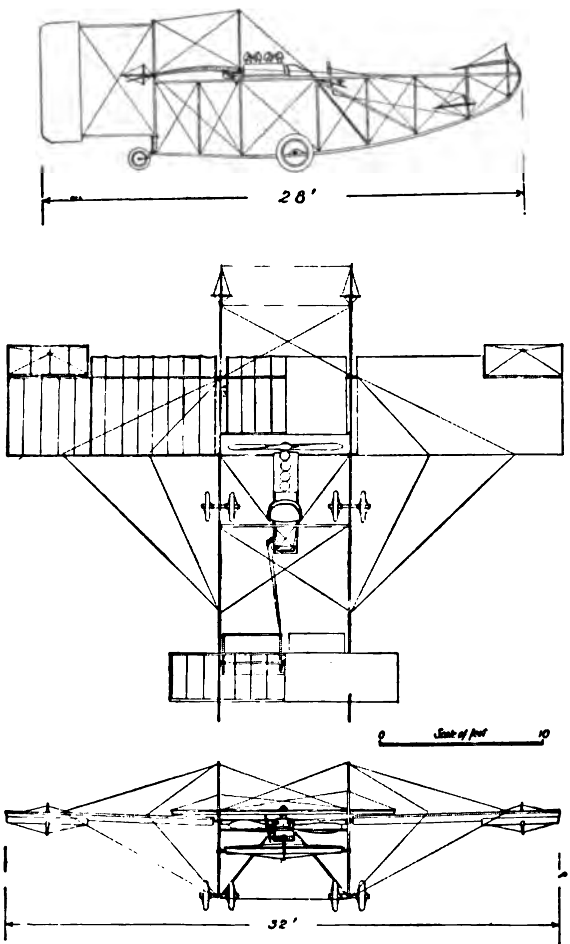
THE VALKYRIE MONOPLANE

18. THE VALKYRIE MONOPLANE

This interesting aeroplane, designed and built by the Aeronautical Syndicate, Ltd., in England, is so distinct a departure from usual monoplane practice, that it has excited a great deal of comment. Many excellent flights have already been made on this

"All-British" machine, and it is speedily taking rank among the prominent types.

The Frame.—A very fine quality of Honduras mahogany is used almost exclusively in the framework. The main members of the frame are two very long skids, upon which the rest of the



SIDE ELEVATION, PLAN AND FRONT ELEVATION OF THE VALKYRIE MONOPLANE frame is built up. These skids are wide apart, and take the place of a central chassis.

The joints of the frame are made of aluminum and are very neat.

The Supporting Plane.—The main plane is made in three sections, the one between the frames and back of the propeller having a similar chord and less incidence than the other sections because of its position in the slip stream of the propeller. The two outer sections of the plane are turned up slightly, giving a dihedral angle effect. The surfaces are made of one layer of an Egyptian cotton fabric stretched tightly over numerous wooden ribs. The plane is braced by cables to the struts and frame of the central section. The spread is 32 feet, the chord 6½ feet, and the surface area 190 square feet.

The Elevation Rudder.—Out at the front, under the horizontal front fixed keel plane, is the single-surface elevation rudder. This is operated by wires leading to a lever which is moved to and fro, as on the H. Farman biplane. The elevator is 8 feet wide, 2½ feet deep, and 20 square feet in area.

The Direction Rudder.—Two identical surfaces at the rear serve as direction rudders. They are controlled by a foot pedal or by the side-to-side motion of the lever, as desired.

Transverse Control.—Ailerons fixed to the trailing edge of the main surface at either end control the transverse balance. They can be operated by pedals or by the side-to-side motion of the lever, as desired. These ailerons are 5 feet wide and 2 feet deep.

Keels.—There is a large horizontal keel placed well out in front, and called the "leading plane," 14 feet wide and 3 feet deep. It exerts a considerable lift, and is set at a greater incident angle than the main surface, thus employing the principle of the dihedral angle for longitudinal balance. The incident angle of this plane can be altered at will. There is no rear tail.

Propulsion.—A 30 horse-power Green engine, placed at the center in front of the main plane, drives direct a 7¼-foot propeller at 900 r.p.m. The position of the propeller is a curious one, working as it does in a slot in the framework.

Mounting.—The mounting of this machine on the strong and serviceable skids is one of its distinguishing features, and one which has been highly praised. There is little doubt that in rough landings a framework of this kind is about as safe and strong as could be desired. It resembles the old Wright frame in many respects. On each skid at the front, below the seat, is fitted a pair of wheels attached by springs, and at the rear are two smaller wheels.

The *Seat* is very conveniently placed out in front of the motor as regards comfort, but in case of accident this disposition is dangerous.

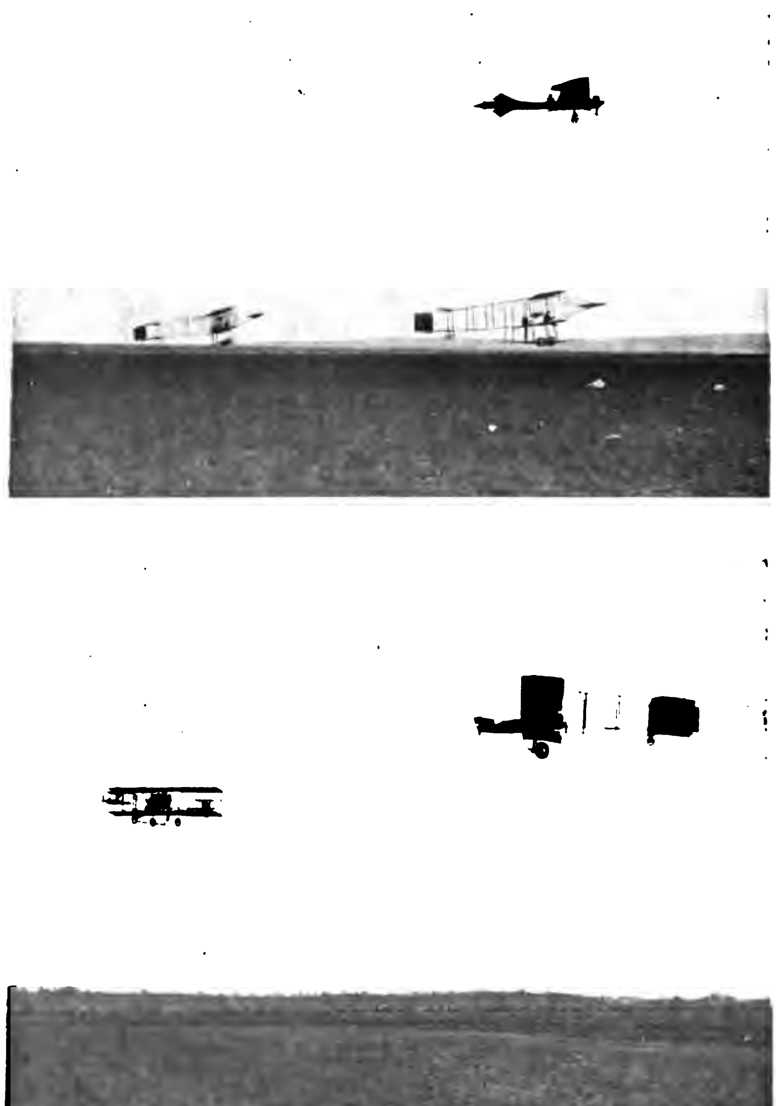
The center of gravity is very far forward, and necessitates a considerable lift on the part of the "leading plane."

Speed, Weight, Loading and Aspect Ratio.—

The speed is about 46 miles an hour. The total weight in flight is 670 pounds; 22½ pounds are lifted per horse-power, and 3.5 per square foot of surface. The aspect ratio is 5 to 1.

A racing type "B" and a passenger type "C" are also built.

References.—Flight, 1910, October 1, p. 792; November 5th.



Several Biplanes in Flight

CHAPTER XI.

PROMINENT TYPES OF BIPLANES

The number of biplanes built and under construction is so large that to give anything like a complete survey of the different makes is almost impossible.

There are, however, at present twenty distinct types, to one or the other of which almost all biplanes bear resemblance. Thus the Howard Wright, the Warchalowski, and the Aviatic, as well as many American biplanes, closely resemble the Farman. The German Albatross biplane is merely a counterpart of the Sommer, and in America there are twenty or more successful "imitations" of the Curtiss type, and a few that follow the Wright. The Caudron S. A. F. A., resembles the other French "tractor screw" biplanes in many respects, and the Euler closely follows the Voisin.

The twenty types of biplanes considered here are:

1. Breguet
2. Cody (1909)
3. Cody (1911)
4. Curtiss
5. Dufaux
6. Dunne
7. H. Farman (1909)
8. H. Farman (Michelin)
9. Maurice Farman
10. Goupy
11. Neale
12. Paulhan
13. Sommer
14. Voisin (1909)
15. Voisin (Tractor)
16. Voisin (Bordeaux)

17. Voisin (Front Control, 1911)
18. Wright (1909)
19. Wright (Model R)
20. Wright (Model B)

1. THE BREGUET BIPLANE

M. Louis Breguet has been experimenting for many years at Douai, France, and has gradually evolved, step by step, one of the most perfect flying machines yet constructed. It is interesting to note that the first successful helicopter to lift a man was built by him in conjunction with M. Richet in 1907, the total weight lifted being 1,100 pounds. The elegance of lines and the simplicity of his new biplane have resulted only from patient and diligent study of the subject. This machine is especially remarkable for its great excess of lifting force and the wonderful steadiness with which it "volplanes."

On April 8th, 1910, the Breguet biplane lifted three people at once and flew with such great ease, that the attention of the aviation world was attracted to Douai. At Rouen, at Rheims, and at many other foreign meetings, the Breguet biplanes, driven by M. Breguet himself and by Bathiat, not only won many prizes for passenger flights, but proved to be extremely speedy and reliable.

During the French Army Manœuvres, M. Breguet, with the late Capt. Madiot, made some excellent reconnoitering trips.

On September 1st, 1910, a flight was made with five persons aboard, the pilot and four passengers making a total load of 750 pounds. This performance was exceeded, by the same machine a few weeks later, when the pilot and five passengers made an excellent flight, the total load carried being about 860 pounds. This performance, however, has quite recently been exceeded by Sommer and Blériot. On December 31st, 1910, the Breguet made a distance flight of 205 miles.

The Frame.—The Breguet biplane is one of the few present-day types in which wooden framework is practically eliminated. A long covered fuselage, rectangular in section at the front and semicircular at the rear, gradually tapers to a point, giving practically a "stream line" form. This frame is made of steel tubing at the front, but at the rear, where great strength is not so necessary, there are some wooden crosspieces. The motor is mounted at the front end; the planes are also at the front; the pilot sits back of the planes with a passenger seat in front of him, approxi-

Courtesy of "Flight."

BATHIAT FLYING ON THE BREGUET BIPLANE AT ROUEN, JUNE, 1910

mately over the center of pressure; and at the rear are carried the rudders.

Supporting Planes.—The framework of the main planes consists essentially of two main steel tube cross pieces to which are fixed the numerous ribs. The ribs are made of a U-shaped piece of aluminum sheeting, and are fastened to the steel tubes by an ingenious elastic joint. The entire frame is covered with a specially smoothed and oiled fabric.

The section of the planes is an evenly curved one, thick and blunt at the front and narrowing to a fine edge at the rear.

The planes are not of the same size, the lower one being smaller than the upper. They are, however, directly superimposed, and are mutually supported and fixed to the framework by only four vertical steel tube struts. The "box cell" arrangement is altogether absent. The planes are braced by steel rods to the central frame, and the usual maze of cross-wires is eliminated. This type of construction reduces the head resistance, and considerably increases the lifting force for a given horse-power.

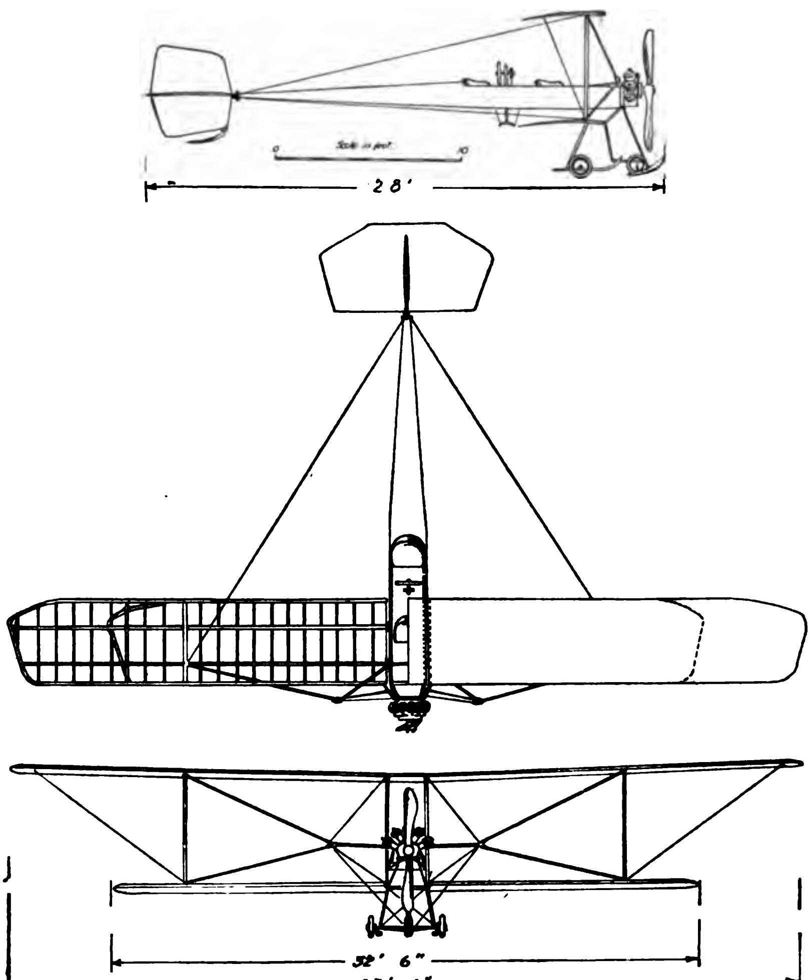
By reason of the great elasticity of the planes, they give a little under pulsations of the wind, and transmit the disturbing forces of the air waves to the frame, greatly diminished. The aeroplane is therefore suspended elastically in its element, and is in consequence assured of a higher degree of stability and a lesser fatigue of its parts.

It is possible because of this elasticity that, similar as it is to the elasticity of a bird's wing, the planes may profit by the "internal work of the wind," and thus is explained, in a measure, their high lifting quality.

The planes are about 7 feet apart. The upper ones are set at a slight dihedral angle. The spread of the upper plane is 43½ feet, the spread of the lower plane 32½ feet, and their depth 5½ feet. The total supporting surface is 409 square feet.

Elevation Rudder.—At the rear of the machine, mounted on a universal joint and held by springs, is a cruciform tail-piece, the horizontal surface of which serves as the elevation rudder. This surface normally is "non-lifting," and has an area of approximately 25 square feet. By pushing forward on the steering column mounted in front of the pilot, the entire tail is turned down, thus lifting up the rear of the machine, reducing the angle of incidence of the main surfaces, and thereby causing the machine to descend. By pulling this column toward him, the aviator causes the machine to ascend.

Direction Rudder.—The vertical surface of the tail serves as the direction rudder, and is moved to either side by operation of the steering-wheel fixed on the control column.



SIDE ELEVATION, PLAN AND FRONT ELEVATION OF THE BREGUET BIPLANE "TYPE MILITAIRE"

Transverse Control.—The transverse equilibrium of the machine is controlled by the ordinary system of warping. By moving the entire control column, wheel and all, to the right, for example, the rear edge of the left plane is turned down, thus increasing the lift on that side.

Keels.—The cruciform tail-piece not only serves as a rudder for both elevation and direction, but in its normal position acts as a stabilizing *keel* of great power. Due to the springy character of this member, the stability is made somewhat automatic. If a sudden gust should hit the under side of the tail, the machine would tend to tilt up at the rear, and therefore descend. But this same gust would cause the tail to be turned up by an amount exactly proportional to the strength of the gust. Since a turning up of the tail is the movement for ascent, the tendency for the gust to cause the machine to descend will be counteracted in proportion to the strength of the gust. Since, in addition, the weight of this machine is great, and its momentum therefore quite large, this form of stabilizing device does actually act, and very forcibly hold, the machine to its course.

Propulsion.—The motor is placed at the front, and drives the propeller through reducing gear. A 40 to 50 horse-power motor is necessary, the usual types used being the Gnome, Renault or R. E. P. The propeller was formerly a three-bladed Breguet metallic one, but of late a two-bladed Chauviere wooden "Integral" has been used, almost 9 feet in diameter, 6½ feet pitch, and rotating at 800 r.p.m.

Mounting.—The mounting is mainly on a set of two heavy rubber-tired wheels fitted on skids with oleo-pneumatic springs under the centre of gravity, and an extra heavy wheel and skid at the front to take very sudden landing shocks and protect the front of the frame, propeller, etc. This wheel can be turned as on an automobile.

Weight, Speed, Loading and Aspect Ratio.—

The total weight of the machine in flight varies from 1,100 pounds with pilot alone, up to 1,800 pounds with six aboard. The speed is approximately 53 miles an hour. The maximum pounds lifted per horse-power are 36, and maximum loading is 4.4 pounds per square foot of carrying surface. The aspect ratio of the upper plane is 7.9 to 1—an extremely high value.

There is also a 60 horse-power "racing type" of Breguet biplane, for which a speed of 62 miles an hour is claimed. The characteristics of this machine are: Spread of upper plane, 40 feet; spread of lower plane, 30 feet; depth, 4¼ feet; surface area, 280 square feet; weight, 1,300 to 1,500 pounds; pounds per horsepower, 25; pounds per square foot, 5.4; and aspect ratio of 7.1 to 1.

References.—Encycl. d'Aviation, v. 2, No. 14, p. 98; Flight, July 16th, 1910, p. 553; December 10th, 1910; Aero, October 26th, 1910; November 2nd, 1910, p. 350; Flugsport, October 19th, 1910. V. Quittner and A. Vorreiter, "Neue Flugzeuge in Paris," Zeit. für Flugtech. und Motorluft., November 26th, 1910; Fachzeit. für Flugtechnik, November 13th, 1910, p. 15; L'Aerophile, February 1st, 1910, p. 58; June 15th, 1910, p. 273; July 15th, 1910, p. 317; December 15th, 1910, p. 558.

References on the Breguet-Richet Helicopters.—L'Aerophile, September, 1907, p. 258; April 15th, 1909, p. 175; La Nature, v. 70, p. 36, 1907.

2. THE CODY BIPLANE (1909)

Col. Cody, an American, who has for some time resided in England, distinguished himself several years ago as the successful operator of man-lifting kites. His work in this line, with regard to army use and scouting, attracted much attention in England. In 1907, Col. Cody commenced work on a motor aeroplane of huge dimensions. At first the tests of this machine were very unsuccessful, but with remarkable perseverance Col. Cody gradually turned the failures into successes, and finally in the late summer of 1909 he accomplished a superb flight of over an hour, establishing then a cross-country record of the world. The machine was altered many times, and in its final form was the largest successful aeroplane ever flown.

The Frame.—Bamboo was used extensively throughout the frame, but all joints were carefully wound with steel wire. In addition there were many upright members of ash. At the center several members met in the supporting chassis which was very heavily built. Steel wire was used for bracing.

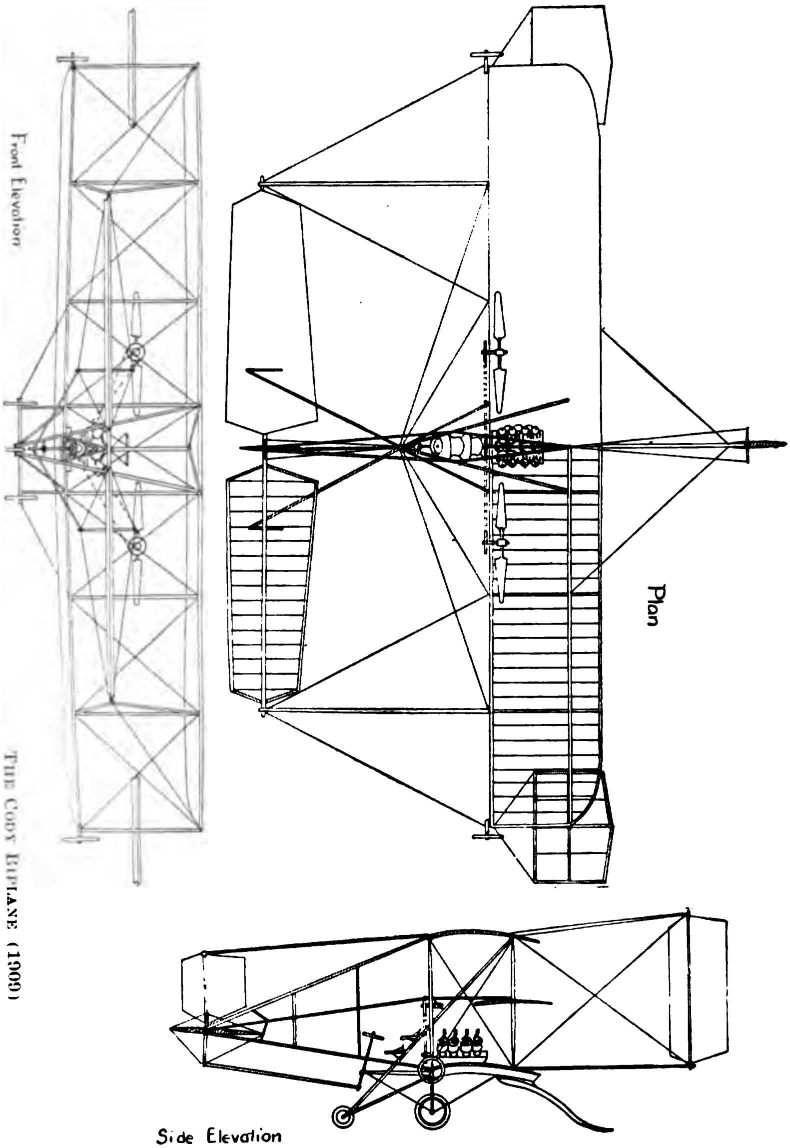
Supporting Planes.—The main planes were rectangular in shape with rounded rear edges and were identical and directly superposed. The surfaces were made of canvas stretched tightly over wooden ribs. At the center the distance between them was 9 feet, but they converged toward either end, and were there separated by only 8 feet. The spread was 52 feet, the depth 7.5 feet, and the area 780 square feet.

The Elevation Rudder.—At the front of the machine, supported by large bamboo outriggers from the central cell, were two

THE 1909 CODY BIPLANE IN FLIGHT

equal surfaces on either side of the center. These were jointly movable, and served to control the elevation of the machine. They were governed by the forward or back motion of the stanchion upon which the steering wheel was mounted. If the aviator wished to rise he pulled the wheel towards him. This motion, by means of a lever system, caused the elevation rudder surfaces to be lifted up to the line of flight and the machine ascended.

The Direction Rudder.—For steering to one side or the other two surfaces were used. At the rear of the machine was a large



THE CODY BIPLANE (1909)

vertical surface, which was the main direction rudder, while at the front was a smaller vertical surface used for the same purpose. These rudders were moved jointly by a cable and steering wheel, as in automobiles or motor boats. Their area was about 40 square feet.

Transverse Control.—Two balancing planes of 30 square feet area, one placed at either end of the main cell, controlled the transverse inclination of the machine. They were moved inversely by cables leading from the steering gear at command of the aviator. If the right end of the machine were depressed, then the wing tip on that side was turned down, but at the same time the wing tip on the other end was turned up. This caused not only the depressed side to rise, but also the raised side to be depressed, thus righting the machine. When making turns the machine could be artificially inclined with this apparatus. In addition to the wing tips, the transverse equilibrium could be controlled by the inverse movement of the two halves of the elevation rudder, the one on the depressed side being elevated while the other was turned down.

Keels.—There were no keels in this machine, all surfaces serving either to lift or to direct the aeroplane.

Propulsion.—The motive power was an 80-horse-power E.N.V. 8-cylinder motor. Two two-bladed propellers placed at the front of the main cell were driven in opposite directions by chains at 600 r.p.m. Their diameter was 8.25 feet, and their pitch 6 feet.

The Seats for aviator and one passenger were placed low at the center in front of the main cell. The lower seat was for the aviator, while the other was designed for the use of an observer in war time to take sketches of the enemy's position, etc.

The Mounting consisted of a large pair of wheels, which carried most of the weight, a small wheel in front of them, and a skid in the rear. Wheels were also fixed on each end of the lower plane to carry the machine easily over the ground if it should alight on one end.

Weight, Speed, Loading and Aspect Ratio.—

The total weight was from 1,900 to 2,100 pounds; the speed, 37 miles per hour; 25 pounds were lifted per horse-power, and 2.57

pounds per square foot of surface. The aspect ratio was 7 to 1.

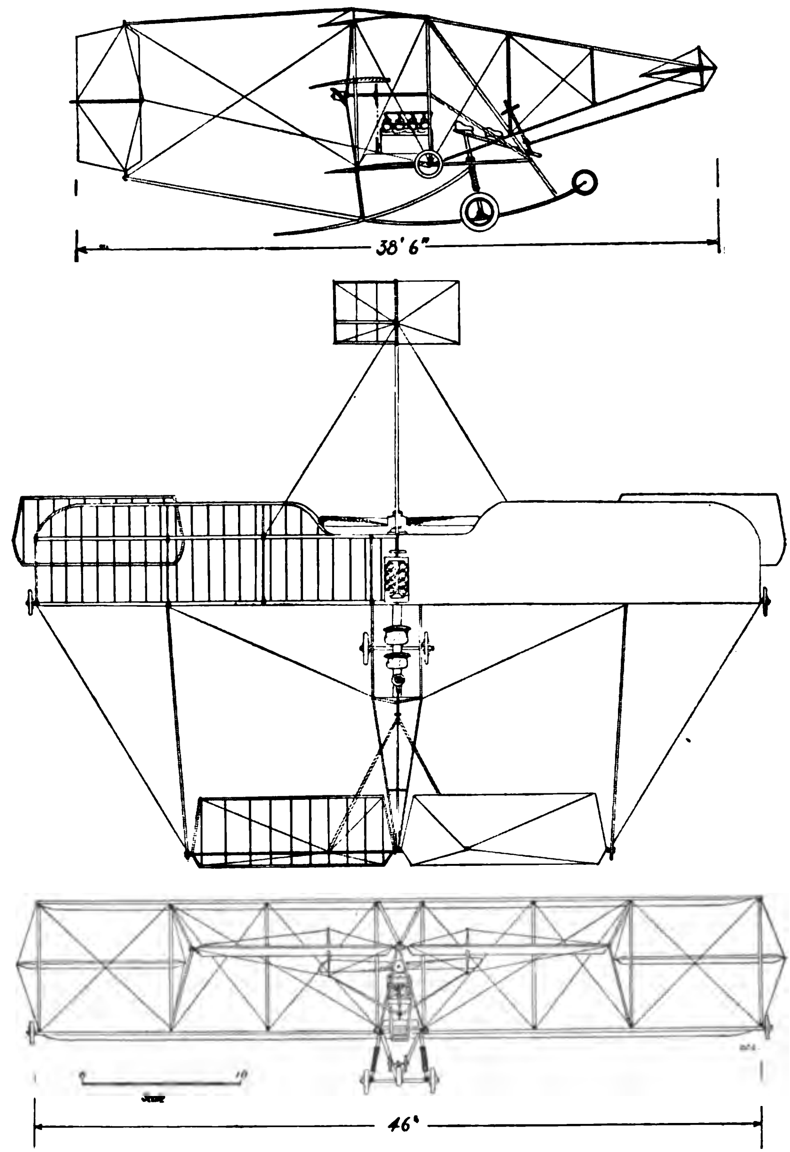
References.—Zeit. Ver. Deut. Ing., v. 53, p. 1143; Aeronautics, v. 4, pp. 78, 126; v. 5, pp. 33, 65, 154; Flight, v. 1, pp. 113, 501; Encyl. d'Av., v. 1, p. 112; Boll. Soc. Aer. Ital., v. 6, p. 288; Vorreiter A., "Motor Flugapparate"; Sci. Am., v. 101, p. 198.

3. THE CODY BIPLANE (1911)

Col. Cody's newest biplane, in which he won the British Michelin prize by flying 186 miles at Farnborough on December 31st, 1910, greatly resembles its predecessor, but is smaller, and distinguished by its equipment with one propeller at the rear instead of two as formerly. The control system and rudders are precisely

Courtesy of "Flight."

MR. S. F. CODY ON HIS 1911 TYPE BIPLANE, COMPETING FOR THE BRITISH MICHELIN CUP, WHICH HE WON BY A FLIGHT OF 186 MILES.



SIDE ELEVATION. PLAN AND FRONT ELEVATION OF THE CODY (1911) the same the balancing forces being distributed over different parts of the machine, thus guarding against any undue local stress. The balancers are held normal by springs.

The Frame.—The frame and skid construction is very much simpler and stronger than formerly. Silver spruce is used in the frame, bamboo for the outriggers, and hickory for the chassis.

The Supporting Planes.—The two planes of the main cell, 8½ feet apart, have a spread of 46 feet, a chord of 6½ feet, and an area of 540 square feet. The depth of curvature is 4 inches,

Courtesy of "Flight."

SIDE VIEW OF THE CODY (1911)

and the shape of the section has a curious narrowing between the spars. The surface is double and made of Pegamoid cloth.

The Elevation Rudder.—The elevating surfaces at the front have a total area of 116 square feet, a depth of 4½ feet, and are 12 feet in front of the main cell. The control is the same as on the 1909 type.

The Direction Rudder.—The front direction rudder is eliminated. The one at the rear is retained, and has an area of 36 square feet.

Transverse Control.—Transverse control is, as on the former type, by means of ailerons and the two halves of the front rudder. The ailerons are each 50 square feet in area.

Keel.—A new departure is the addition of a horizontal non-lifting keel at the rear.

Propulsion.—A 60 horse-power E. N. V. or Green motor, placed on the lower plane, drives by chain a single large wooden-bladed propeller, 10½ feet in diameter and 10.6 feet pitch, at 600 r.p.m. This is the largest propeller used on any aeroplane up to the present.

A new and smaller type with a 35 horse-power engine is being built.

Speed, Weight, Loading and Aspect Ratio.—

The speed of this machine is about 41 miles an hour. The total weight is 1,350 to 1,500 pounds; 25 pounds are lifted per horse-power, and 2.8 per square foot of surface. The aspect ratio is 7.1 to 1.

References.—Flight, 1910, November 12th, p. 923; November 19th, p. 945; Aero, 1910, October 5th, p. 276; October 12th, p. 288, Fachzeit. für Flugtechnik, No. 42, p. 19.

4. THE CURTISS BIPLANE

The Curtiss biplane, originated by the Herring-Curtiss Company, embodies in its construction several features that distinguished the aeroplanes built by the Aerial Experiment Association, of which Mr. Curtiss was a member. In June, 1909, the first flight of this type was made. At Rheims, in August, this miniature biplane, ably piloted by Mr. Curtiss, captured the Gordon Bennett Prize and Cup as well as several others. It is one of the fastest biplanes now in use. Several machines of this type are being flown, notably by Messrs. Curtiss, Mars, Hamilton, Willard, McCurdy, Ely, Post, and Baldwin. There is no other type that has been as widely imitated by amateurs in this country as the Curtiss.

The Frame.—The main cell and smaller parts are made of ash and spruce, and the large outriggers, of bamboo. Several members of the frame meet at the front wheel. Small cables as well as wires are used for bracing.

The Supporting Planes.—The main carrying planes are of very finished construction. They consist of two identical directly superposed surfaces made of one or two layers of Baldwin rubber silk, tacked to spruce ribs and laced to the frame. A distance of 5 feet separates the surfaces. Their spread is 26.42 feet, the depth 4.5 feet, and the area 220 square feet.

The Elevation Rudder.—The elevation rudder is a small biplane cell consisting of two identical surfaces, 24 square feet in area, mounted at the front on bamboo outriggers. It is governed by a long bamboo rod attached to the stanchion on which the steering wheel is mounted. By pushing out on this, the rudder is turned down and the machine descends. By pulling in, the machine is caused to ascend.

THE CURTISS BIPLANE, WHICH WON THE INTERNATIONAL CUP AT RHEIMS IN AUGUST, 1909

The Direction Rudder.—The rudder for steering from right to left consists of a single vertical surface placed in the rear and operated by the steering wheel and cables, which are run inside the bamboo outrigger. Its area is 6.6 square feet.

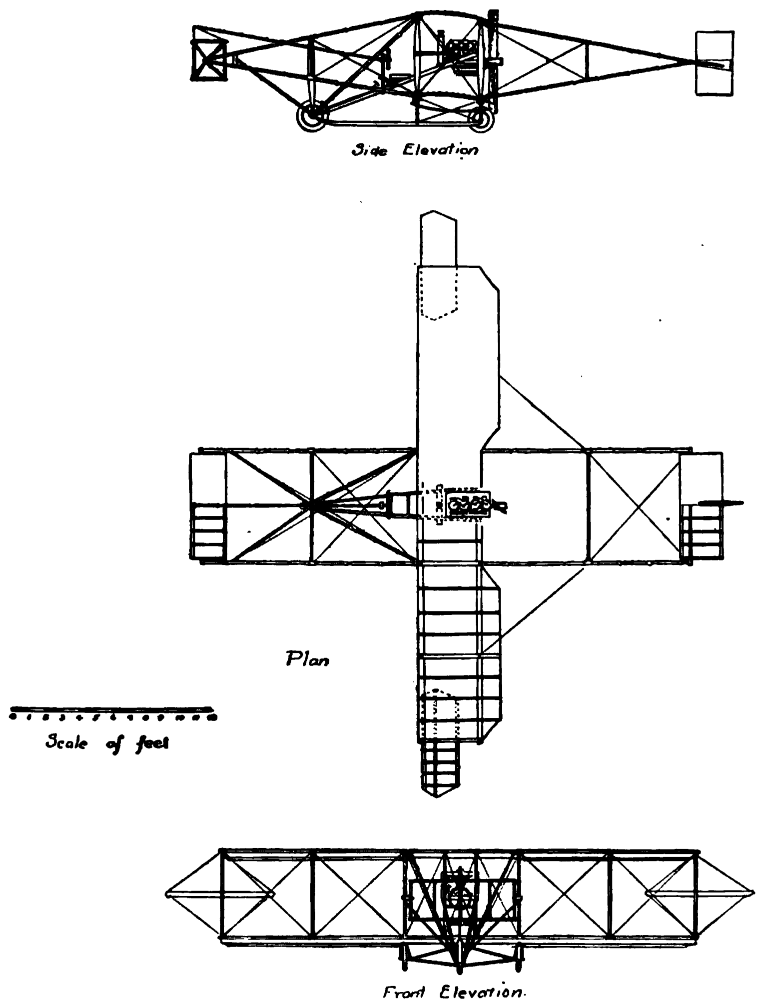
Transverse Control.—Two balancing planes of 12 square feet area each, one placed at either end of the main cell, are used to preserve lateral balance. They are tipped inversely by means of a brace fitted to and swayed by the aviator's body. If the machine is depressed on the left side, the aviator leans toward the right, and in so doing moves the brace, causing the wing tip on the left side to be turned down and the one on the right to be turned up, thus righting the machine. By "turning down" is here meant a motion relative to the axis of the wing tip itself and not to the line of flight. When a wing tip of this sort is turned down, its incidence, i. e., the angle it makes with the line of flight, is positive and it therefore exerts a greater lifting force.

GLEN CURTISS AFTER HIS ALBANY-NEW YORK FLIGHT

When making a turn to the right, for example, the aviator, by leaning to the right, and thus causing the left end to lift up, can make a sharper turn than by use of the direction rudder alone.

Keels.—A horizontal fixed surface is placed in the rear and steadies the machine greatly. Its area is 15 square feet. A small triangular vertical surface is sometimes placed in front.

Propulsion.—A 25 horse-power, 4-cylinder Curtiss motor, placed well up between the two surfaces at the rear, drives direct a two-bladed wooden propeller at 1,200 r.p.m. The propeller has a pitch of 5 feet and a diameter of 6 feet.



PLAN AND ELEVATIONS OF THE CURTISS BIPLANE

The Seat for the aviator is on the framing in front of the main cell and in line with the motor. When a passenger is carried a seat is provided to the side and somewhat below the aviator.

The Mounting is on three rubber-tired wheels, rigidly fixed to the frame, no springs being provided.

Weight, Speed, Loading and Aspect Ratio.—

The total weight is from 530 to 570 pounds, and the speed is 47 m.p.h.; 22 pounds are lifted per horse-power and 2.5 pounds per square foot of surface. The aspect ratio is 5.65 to 1.

A NEAR FRONT VIEW OF A CURTISS BIPLANE

Recent Alterations.—Mr. Willard has recently flown a larger type of Curtiss biplane, in which he has succeeded in carrying three passengers besides himself.

This machine is precisely of the same general design as the regular Curtiss type, but differs from it in size.

The supporting planes have a spread of 32 feet, a depth of 5 feet, and an area of 316 square feet. The elevation rudder is 31 square feet in area, and the direction rudder 7.5 square feet in area. The rear horizontal keel has an area of 17.5 square feet, while the ailerons are each 27 square feet in size. A Curtiss 8-

cylinder 50 horse-power motor is used and drives direct a 7-foot propeller at 1,100 r.p.m. The maximum total weight in flight is 1,150 pounds. 22.6 pounds are carried per horse-power, and 3.64 pounds per square foot of surface. The aspect ratio is 6.4 to 1.

In most of the latest Curtiss machines, a single plane elevation rudder is used, and the side ailerons are replaced by four flaps on the trailing edges of the planes, or are placed on either side at the rear of the cell.

In the new machine used by Mr. Curtiss in his recent interesting experiments over water, the single plane elevation rudder is aided in its action by movable flaps on the rear of the horizontal keel at the back, a disposition similar to that used on the Farman biplanes. The fan shape of this rear keel as on Mr. Ely's machine is also a new departure.

References.—Aeronautics, v. 5, p. 13, 86. 137; Am. Aeronaut, v. 1, p. 1 (new series); Boll. Soc. Aer. Ital., v. 6, p. 286; SCI. AMERICAN, v. 100, p. 460; Encycl. d'Av., v. 1, p. 24; Am. Machinist, v. 32, p. 49; Flight, v. 1, p. 389; Zeit. für Luft., v. 13, p. 816; Aerophile, v. 17, p. 488; Locomocion Aerea, v. 1, p. 78; Genie Civil, v. 55, p. 343.

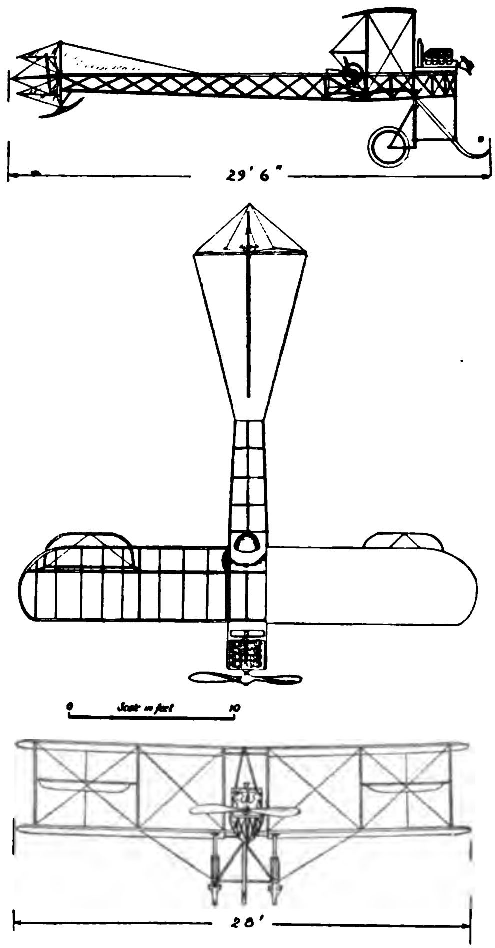
5. THE DUFAUX BIPLANE

This biplane, built in Switzerland by the Dufaux Brothers, is one of the most successful types of biplanes equipped with a tractor screw. It is noteworthy for its light weight. Excepting the main surfaces, the Dufaux resembles the Antoinette more than any other type, and possesses some of the gracefulness that is so characteristic of that monoplane. Many excellent flights have been made by this machine, among them a 36-kilometer flight on July 12th, 1910. Toward the end of August, the Dufaux biplane was flown across the Lake of Geneva, a distance of 41 miles, with perfect ease and at high speed.

As early as October, 1905, the Dufaux Brothers were experimenting with heavier-than-air machines. At this date they had built a very light engine and applied it to a helicopter. This apparatus succeeded in lifting 54 pounds.

In the summer of 1908, an interesting triplane was built by them, 650 square feet in area and equipped with a 125 horse-power eight-cylinder motor. The total weight was 1,400 pounds.

The Frame.—The long central frame or *fuselage* of the Dufaux is similar to that of a monoplane, and the latticed framework itself reminds one strongly of the Antoinette. The disposition of



THE DUFAUX BIPLANE, SIDE ELEVATION, PLAN AND FRONT ELEVATION parts is exactly as on the ordinary monoplane, the motor and propeller being at the front, the rudders and keels at the rear, and the seat just back of the main planes.

The Supporting Planes.—The main planes are similar and directly superposed. They are constructed of the usual wooden framework covered above and below with rubber fabric. The two halves of the main cell are set at a slight dihedral angle. Their curvature is quite flat and narrow. The spread is 28 feet, the depth 5 feet, and the area 260 square feet.

Elevation Rudder.—The elevation rudder consists of a single horizontal surface at the rear, triangular in shape, and operated by a wheel at the aviator's right hand, exactly as on the Antoinette.

Direction Rudder.—The direction rudder consists of two triangular surfaces at the rear, similar to those on the Antoinette, but smaller. The direction is controlled by a foot pedal, which is turned to the right or left, according as the desired turn is to right or left.

Transverse Control.—The transverse control is effected by the use of ailerons, one pivoted at the rear of the main cell on either side and midway between the planes. The ailerons are operated by a lever in the aviator's left hand. By pulling the lever to the right, for example, the left aileron is turned down, thus increasing the lift on the left side.

Keels.—A vertical keel and a horizontal keel or *empennage,* both of which terminate in their respective rudders, are provided and greatly resemble the Antoinette.

Propulsion.—An eight-cylinder E. N. V. 50 horse-power motor is mounted at the front. The propeller is driven direct at 1.300 r.p.m., and is 7 feet in diameter. A radiator is placed back of the motor.

Mounting.—The mounting is essentially on two wheels fitted with springs on a steel tube chassis (*à la* Blériot) with a single skid projecting out in front at the center, similar to the Antoinette. There is also a small skid at the rear.

Weight, Speed, Loading and Aspect Ratio.—

The total weight in flight is about 550 pounds; 11 pounds are lifted per horse-power; and 2.1 pounds are carried per square foot of surface. The aspect ratio is 5.6 to 1.

References.—L'Aerophile, January 15th, 1910, p. 31; October 1st, 1910; Flight, August 27th, 1910, p. 696.

6. THE DUNNE BIPLANE

The Dunne biplane, constructed in England by Short Brothers to the design of Lieut. J. W. Dunne, is very solidly built and presents a very unusual appearance. In the numerous flights that have been made at East-church, Isle of Sheppey, exceptional stability was exhibited by this biplane, and since its outstanding features are the absence of the usual elevation and direction rudders, and the curious shape of the main cell, it has excited much interest and comment.

It is said that the British army experimented with a prototype of this machine, in secret, some years ago.

The Frame.—The construction of the main cell is of the usual wooden and wire frame, canvas-covered type. At the centre there is built in a skiff-like body 18 feet long containing the motor, seat, controlling levers, radiator, etc.

The Supporting Planes.—The conspicuous feature of this machine is the employment of the dihedral principle, laterally, transversely, and longitudinally.

The general aspect of the main planes are evident from the accompanying scale diagrams.

The greatest fore and aft direction is constituted by the wings themselves.

The incidence of the tips is much less than the incidence at the center. In flight the angle is very low indeed, and is certainly negative at the ends. The camber of the ribs is a very interesting feature. At the center the ribs have their greatest depth of camber far to the front, with a long straight portion to the rear. But at the ends the ribs are curved so that the greatest depth of camber is about at the center. The theory involved in this type of construction is very interesting, and indicates that by making use of the variations in position of the center of pressure a semi-automatic balance is obtained.

The planes are 6 feet apart, 6 feet in depth, and spread 20 feet 4½ inches longitudinally and 46 feet laterally. The total area is 527 square feet.

Elevation.—At the rear ends of each plane are hinged flaps, each 7½ feet wide and 12½ square feet in area, controlled by a left-hand and a right-hand lever. They are so connected that when the right-hand lever is pulled back, and the left-hand lever is

Courtesy of "Flight."

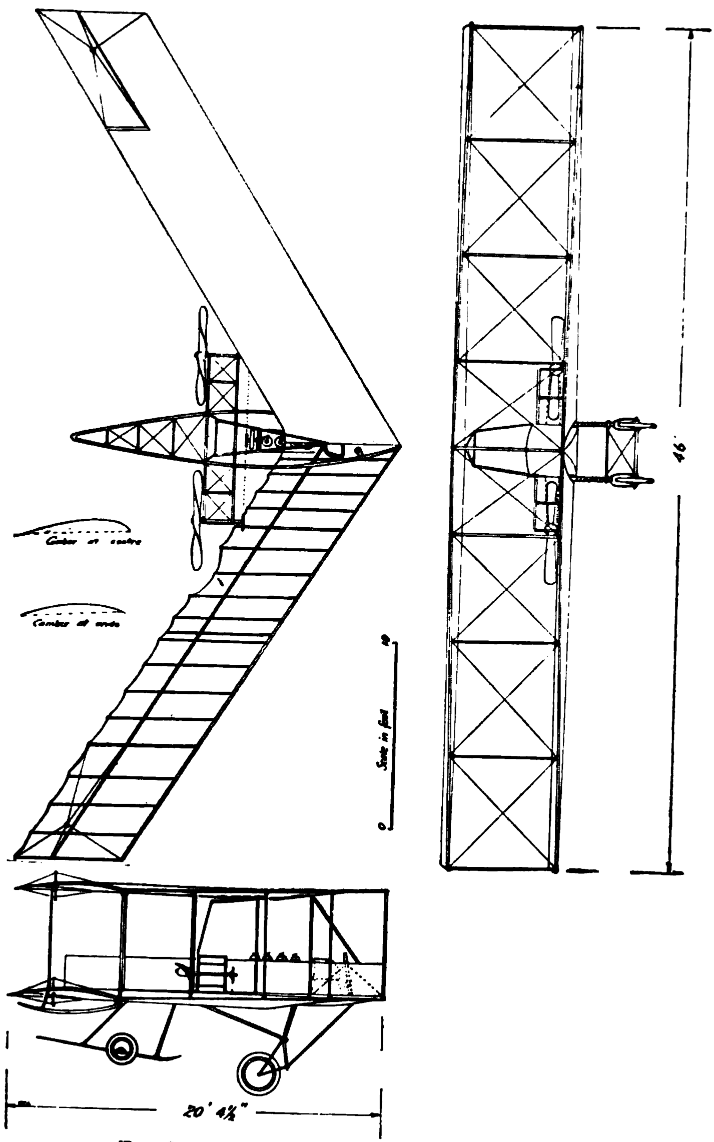
A REAR THREE-QUARTER VIEW OF THE DUNNE BIPLANE

This photograph is worthy of study because it gives the correct impression of the shape, and slope of the main planes.

pushed forward, then the left ailerons are pulled down, lifting up that side and the right ones are turned up. When both levers are pulled back together, both flaps are turned up, and since they are to the rear of the center of support, the entire machine will be turned up for ascent.

Direction.—When steering to the right, for example, the right lever is drawn back and the left pushed forward. thus pulling up the right flap and pulling down the left.

The angle of incidence of the ends is always negative. Therefore turning up the right flap increases still further the negative incident angle, and consequently greatly increases the negative drift, thus causing the right side of the machine to slow down, at the same time as it is depressed. But since the flaps are at the



THE DUNNE BIPLANE. PLAN AND ELEVATIONS

rear of the center of gravity, and since turning up the right flaps causes this end to sink (like the tail of a Blériot, for example), there is a tendency for the entire machine to ascend. To counteract this, the left lever is pushed over, thus increasing the lift on this end and decreasing the negative incident angle. This now results in a decrease of drift on this side, and causes the machine to "skew" around faster and to "bank" with the right down and the left up.

Transverse Control.—The character of the planes on this biplane give it practically an automatic transverse equilibrium, so that there is no distinct and separate manner of controlling the lateral inclination of the machine. The manner in which this aeroplane is artificially inclined when making turns, however, has already been described.

Keels.—The end panels of the main cell are covered-in, giving a vertical keel at each side, which aids materially in the various movements for equilibrium and holds the machine to its course, preventing any skidding sideways, etc.

Propulsion.—Two wooden propellers are mounted on a frame built out on either side of the central body. These propellers are 7 feet in diameter, 7½ feet pitch, and rotate at 660 r.p.m. They are driven by chains from a 50 horse-power four-cylinder Green engine, and are rotated in the same direction. To counteract the torque resulting from this, a weight is fixed on one end of the machine. This is not a very good provision.

Mounting.—The mounting is similar to the old Voisin type, and consists of two rubber-tired wheels mounted on a steel-tube chassis fitted with coiled steel springs at the front and a single wheel and skid at the rear.

Weight, Speed, Loading and Aspect Ratio.—

The total weight in flight is about 1,700 pounds, 34 pounds are lifted per horse-power, and 3.2 per square foot of surface. The aspect ratio, considering the actual width of the planes, is 9 to 1, and considering the projected span of 46 feet, is 7.6 to 1.

References.—**Flight, June 4th, 1910; June 18th, 1910, p. 459; June 25th, 1910; Flugsport, July, 1910.**

GRAHAME-WHITE ON HIS FARMAN BIPLANE AT BOSTON, SEPTEMBER, 1910

7. THE FARMAN BIPLANE (1909)

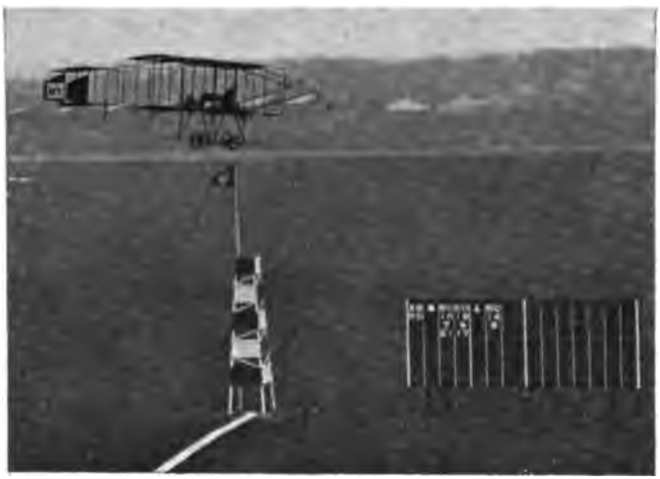
Henri Farman, in 1907, began his career as an aviator by making short flights of a few seconds duration on a biplane constructed for him by the Voisin brothers. On January 13th, 1908, he succeeded in flying one kilometer in a closed circuit, thereby winning the Deutsch-Archdeacon prize, the first great prize offered for an aeroplane flight. Until the end of that year Farman flew this machine and with it conducted a series of experiments on stability. In the early part of 1909, having severed his connection with the Voisins, Farman opened an aeroplane factory at Chalons, France, and began manufacturing aeroplanes himself. His design was original in many ways, and embodied several practical innovations that his previous experience had suggested.

The Farman biplane has been used extensively in Europe, and notably by the well-known aviators Paulhan, Weyman, White, etc. More than one hundred of this type are in use or under construction, and for a slow but trustworthy machine it has been found very satisfactory.

The Frame.—The frame consists essentially of a main box cell, somewhat similar in design to a Pratt truss, counterbraced throughout, with identical upper and lower chords, uprights of wood acting as compression members and cross wires as tension members. The supporting planes are analogous to the upper and lower decks of such a truss.

The Supporting Planes.—There are two main carrying surfaces, identical and directly superposed. Their sectional curvature is of the cambered shape, used so generally in present day aeroplanes. The curvature is concave on the under side, and of parabolic character. The surfaces are made of "Continental" cloth, a special rubber fabric, stretched tightly over ash ribs. The spread of the surfaces is 33 feet; the depth, 6.6 feet, and the total area, 430 square feet. The distance between planes is 7 feet.

The Elevation Rudder.—The elevation rudder originally consisted of a single surface, about 43 square feet in area situated well out in front. It was hinged and braced to two sets of outriggers, firmly attached to the main cell, and was controlled by a large lever in the aviator's right hand. By pulling in on this lever, the rudder was tilted up and the machine was caused to rise. By pushing out on the lever, the rudder was dipped down and the machine was caused to descend. This method of control is almost instinctive and very easy to acquire. On the more recent types this front rudder is reduced in size and in addition the rear flap of the upper keel at the stern is moved jointly with it.

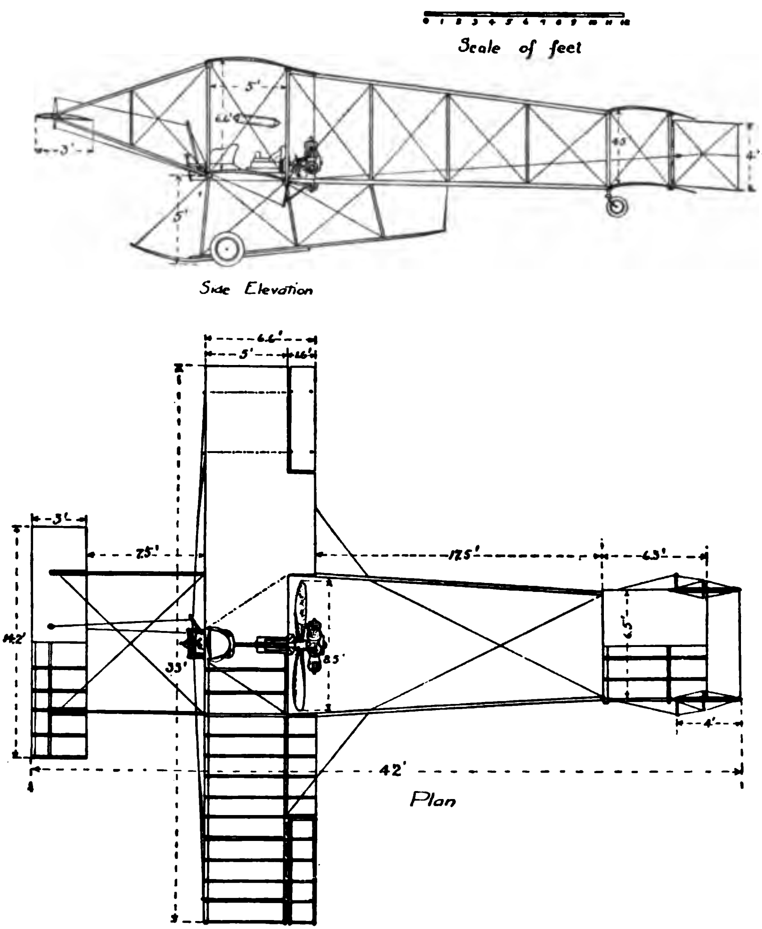


GRAHAME-WHITE ON HIS FARMAN AT BELMONT PARK

The rudders and ailerons are all in their normal positions. The bulletin board indicates that he has just completed 19 laps in an hourly distance event. Note the hangars and tents in the distance.

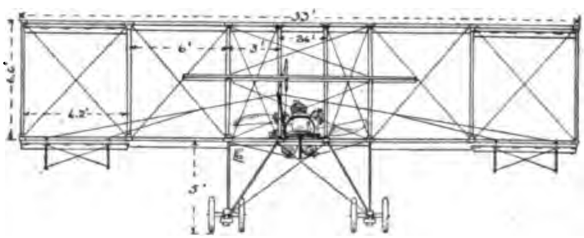
The Direction Rudder.—Two equal vertically placed surfaces in the extreme rear serve as the direction rudder. They are moved jointly and have an area of approximately 30 square feet. A foot lever, hinged at its center, is so connected to these rudders by cables that when the aviator pressing on this lever with his feet turns it, for example, to the left, then the machine will turn to the left.

Transverse Control.—The control of the lateral equilibrium i. e., the tipping from side to side, is effected by the use of "wing tips," four flaps constituting the rear ends of each plane. A lever in the aviator's right hand (the same one as used to operate the elevation rudder) can be moved from side to side. It is connected by wires to the lower flap on either side. These flaps in turn transmit the movement imparted to them by the lever to the flaps



SIDE ELEVATION AND PLAN OF THE FARMAN BIPLANE WITH WHICH HENRI FARMAN WON THE MICHELIN PRIZE IN 1909 directly above them by means of a further wire connection. When the machine is standing still the flaps merely hang down loosely and the wires relax. But as soon as the machine takes to flight the flaps fly out, very much like a flag blown by the breeze, and in this position the connecting wires are extended their full length, and the lever is in control.

If, for example, the machine should tip suddenly down on the aviator's right side then the lever is promptly moved over to the left. This action causes the flaps on the right end of the machine to be pulled down, and since this involves an increased angle



FRONT ELEVATION OF THE FARMAN BIPLANE

of incidence of the flaps, the lift they exert is increased. This is sufficient to bring the machine back to an even keel. During this process the wires leading to the flaps on the other end have been relaxed, since both sets of connecting wires are taut only when the lever is in mid-position. The flaps on the opposite end, therefore, have in no way been affected, except to be able to fly out more freely in the wind stream.

When making turns, in addition to using the direction rudder, the machine is often artificially inclined by the use of the transverse control. When turning to the right, for example, an instant before setting the direction rudder the lever is moved over to the right side. This lifts up the left end of the machine and therefore causes the turn to be sharper.

Keels.—Two horizontal surfaces at the rear, of approximately 80 square feet area, act as keels. Their angle of incidence is low, and the lift they exert is small, their only function being to steady the machine longitudinally.

THE GNOME ENGINE PROPELLER AND FUEL TANK OF PAULHAN'S FARMAN BIPLANE

Note the rubber band spring between the skid and axle of wheels.

Propulsion.—A 50 horse-power 7-cylinder, Gnome rotary, air-cooled motor is mounted on a shaft in the rear of the lower plane. A two-bladed Chauviere wooden propeller is directly connected to this motor and rotates with it at 1,200 r.p.m. The pitch of the propeller is 4.62 feet and its diameter is 8.5 feet.

HENRI FARMAN WITH 2 PASSENGERS

Note the control levers and wires leading to the rudders and ailerons.

The Seats for aviator and two passengers are placed on the front of the lower plane.

The Mounting, or apparatus upon which the machine starts and alights, consists of two long skids forming part of the framework, upon each of which is mounted a pair of wheels. When starting, this machine runs along the ground on its wheels, but when alighting, the wheels, which are attached to rubber springs, give way, and the machine lands on its skids.

Weight, Speed, Loading and Aspect Ratio.—

The total weight varies greatly with the amount of gasoline taken aboard, the number of passengers, etc. The limits within which this value lies, however, are given and all calculations are made for an approximate mean weight of the machine with aviator aboard ready for flight. The weight of the Farman machine is from 1,100 pounds to 1,350 pounds; the speed, 37 miles per hour; 24 pounds are lifted per horse-power and 2.8 pounds per square foot of surface. The aspect ratio is 5 to 1.

Recent Alterations.—Some of the more recent types of Farman machines are fitted with a single surface direction rudder, instead of the twin surfaces. The elevation rudder, in front, is made smaller, and in addition the rear end of the upper of the two fixed horizontal keels (at the rear of the machine) is made movable conjointly with the front rudder to control the elevation of the machine as already noted. In some of the machines only one surface is used at the rear.

The two small wheels supporting the rear cell are replaced by a single skid. Other characteristics are substantially as given.

The new racing type of Farman has the following characteristics: The surface is reduced to 350 square feet, and the spread to 28 feet. The total weight in flight is about 1,050 pounds. Twenty-one pounds are lifted per horse-power, and 3.0 pounds per square foot of surface. The aspect ratio is 4.2 to 1.

References.—Aerophile, v. 17, p. 220, p. 488; Aeronautics, v. 4, p. 206; v. 5, p. 218; Flight, v. 1, p. 641; Flug Motor Tech., No. 22, p. 10; Boll. Soc. Aer. Italiano, v. 6, p. 288; Locomocion Aerea, v. 1, p. 78; Aeronautics (Brit.), v. 2, p. 117; SCI. AM. SUP., v. 68, p. 324; La Nature, v. 37, p. 329.

8. THE "FARMAN MILITAIRE" BIPLANE (TYPE MICHELIN)

Henri Farman on this machine established the world's record for duration of flight, when on December 18th, 1910, he flew continuously for almost eight hours and a half. This wonderful

HENRI FARMAN ON THE "TYPE MICHELIN," WITH WHICH HE ESTABLISHED A DURATION RECORD OF 8h. AND 23m. ON DEC. 18, 1910, COVERING 288 MILES. Note the enclosed body and huge fuel tanks.

achievement was really made possible by the great weight-lifting capacity of this type, enabling him to carry almost 450 pounds of fuel in an enormous tank. The "type militaire" is remarkable for its great size, the newly adopted inclosed body, the dihedral angle of the planes, and its three direction rudders. This type is very steady, slow, and capable of making trips that it would tax many an automobile to make, and that in fact few trains can accomplish. A slightly smaller type has attained great success.

Weyman made his flight from Paris to Clermont, 420 kilometers, in seven hours, on a biplane of this type. Wynmalen made the round trip between Paris and Brussels with a passenger far quicker than the fastest express train, and in many ways with greater security.

Height records, distance records, five-passenger-carrying records, and a great variety of special prizes have been made and won by this type and types similar to it. The slow speed does not at all indicate that the type is inefficient, but on the contrary, makes it far safer and far more serviceable, especially in military work, where hovering over one spot is of great importance.

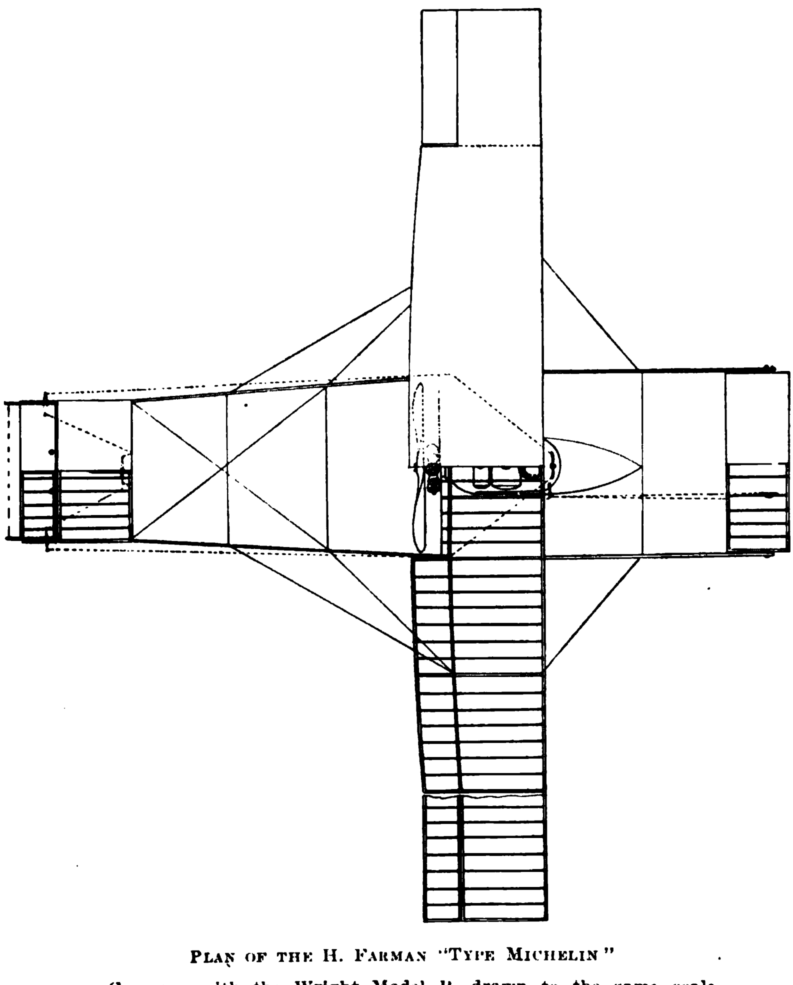
Almost unlimited are the possibilities of practical utilization in commerce, in war, and in recreation, of a type of this character, capable of flying from sunrise to sunset without ever touching *terra firma.*

The Frame.—The details of the framework and the general character of the main cell, outriggers, rear cell, etc., are similar to the other Farman types; steel tubing, however is more generally used. A new departure is the introduction of a covered central body, containing the seats, the tanks, etc., and shaped to a stream line form, very much as on the Maurice Farman. The outer panels of the upper plane are hinged and held in place by an inclined movable steel tube strut enabling these parts to be folded down when not in use. This disposition was first installed on the smaller Farman of Fischer.

The Supporting Planes.—As on many of the Farman biplanes of 1910, the lower plane is made shorter than the upper. The spread on the upper plane is 49¼ feet and that of the lower 36 feet. The total area is 540 square feet, which makes this the same size as the Cody.

The entering edge of the upper plane is horizontal, but the trailing edge is curved up from the center, thus giving to the upper plane an incident angle which gradually decreases from the center to the ends. This is supposed to increase stability and lift. The entire lower surface is set at a dihedral angle which is rather large.

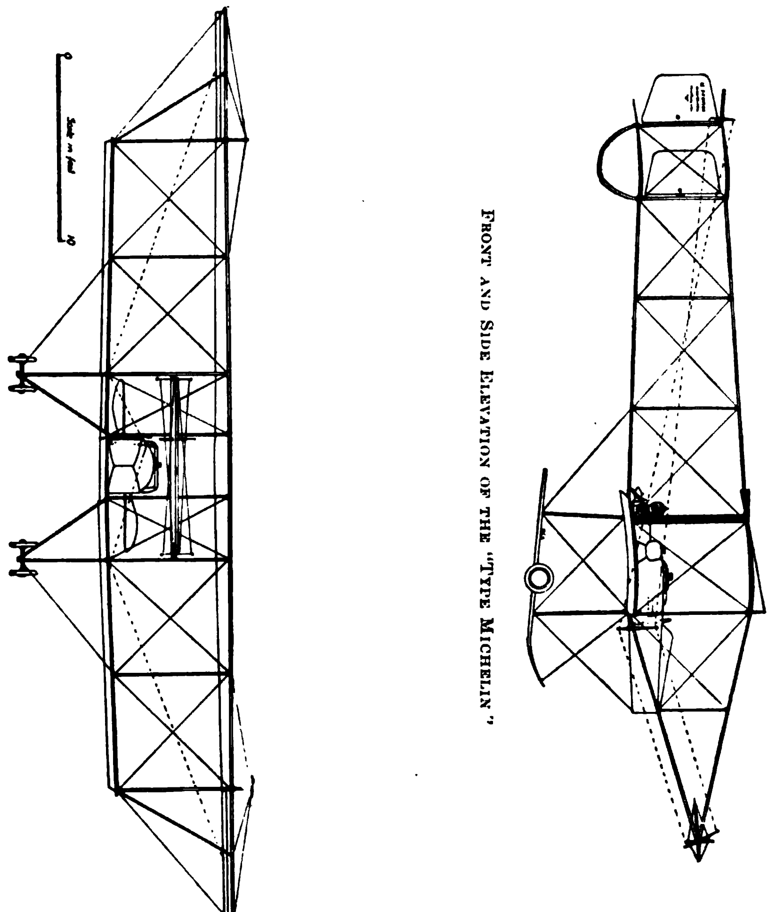
The Control System.—The rudders and controlling system are the same as on the other type—a front elevation rudder com-



PLAN OF THE H. FARMAN "TYPE MICHELIN"

Compare with the Wright Model R, drawn to the same scale.

bined with the movable trailing flap on the upper surface of the rear cell, and ailerons on the outer ends of the upper main surface. Three direction rudders instead of two are installed.



FRONT AND SIDE ELEVATION OF THE "TYPE MICHELIN."

Some of the earlier "types militaires" were equipped with an aileron on each end of the lower panel and two above, making six in all.

The *motion power* is the usual seven-cylinder 50 horse-power Gnome plant, with an Eole propeller.

Weight, Speed, Loading and Aspect Ratio.—

The total weight is from 1,300 to 1,850 pounds. The speed is about 34½ miles an hour; 37 pounds are lifted per horse-power,

FRONT VIEW OF THE "TYPE MICHELIN"

and 3.4 pounds per square foot of surface. The aspect ratio is 6.8 to 1.

References.—SCI. AM., December 31st, 1910, p. 516; Aero, December 7th, 1910, p. 451; December 14th, 1910.

9. THE MAURICE FARMAN BIPLANE

Early in 1909 Maurice Farman, a brother of the pioneer, Henri Farman, began his career as an aeroplane constructor, rivaling in due time his brother. Although up to the late summer of 1910 they conducted their business separately, the Farman brothers are now working in partnership, the H. Farman and the M. Farman being two types made by the same firm.

The first M. Farman biplane was constructed by M. Mallet and tried at Buc in January, 1909. In this machine the planes were warped, although the general aspect was the same. Since then this type has been greatly refined. It is to-day an excellent and well-built machine, and has attained conspicuous success. M. Farman has made many notable flights with this machine. Among the other pilots are Lieut. Byasson, who flew from Paris to Chartres and back, the last week in October, 1910. Capt. Etévé and Lieut. Lucas, former Wright pupils, are now flying this type. Only recently,

THE MAURICE FARMAN BIPLANE
Tabuteau Winning the 1910 Michelin Prize.

in the first week of November last, Maurice Tabuteau flew on this machine for 6 hours 1½ minutes at Buc, covering a distance of almost 300 miles. This record was later bettered by Legagneux on a Blériot, and again broken by Tabuteau himself, who, on December 30th, won the 1910 Michelin prize and established the world's record for distance without a stop by flying 362½ miles in about 7½ hours. No railroad train in the world goes as great a distance without stopping.

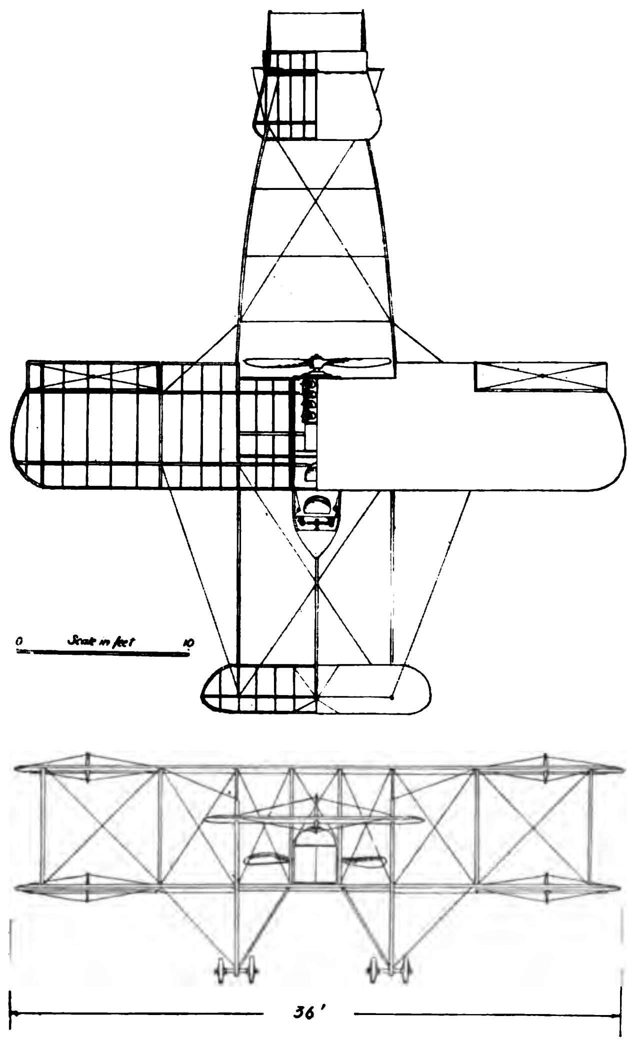
The Frame.—The frame of the main cell is made of the customary wood and crosswire construction. The planes, however, project out in front of the front line of struts, and are not flush with them, as in most biplanes. Outriggers unite the long curved skid to the frame in front, and the cell at the rear is supported on the usual H. Farman-Voisin type framework.

The Supporting Planes.—The main surfaces consist of a frame of wooden ribs and cross pieces, covered above and below with canvas. The planes are curved in plan at the ends, giving a very graceful appearance. The section is exceptionally flat, and lacks altogether the pronounced "dipping edge." The camber rise is only 1/25 of the chord. The spread is 36 feet, the depth 7.5 feet, and the area 510 square feet.

The Elevation Rudder.—At the front is situated a single-surface elevation rudder. The two horizontal planes of the rear cell have pivoted trailing edges, which are moved jointly with the front elevator. The control is by a rod leading to the front elevator and wires leading to the rear flaps, all connected to the bar upon which the steering wheel is mounted. By pulling in on this bar the front elevator is tilted up and the rear flaps tilted up, so that the machine rises.

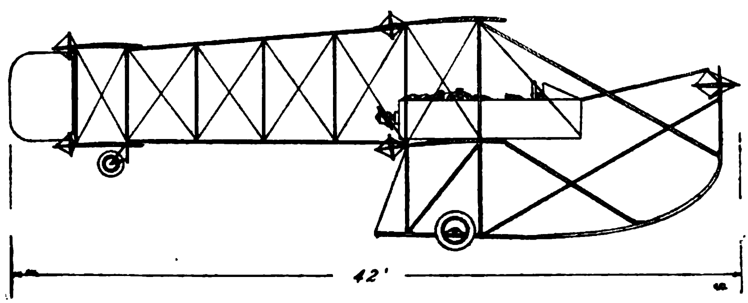
The Direction Rudder.—Two vertical surfaces are hinged to the rear struts of the rear cell. These move jointly and serve as the direction rudder. They are moved by the steering wheel and a lever and wire connection. Turning the wheel to the right, clockwise, for example, will cause the machine to turn to the right.

Transverse Control.—The rear edges of both planes are fitted with hinged ailerons; these are controlled by foot pedals, a disposition which has recently been introduced in France and found very instinctive. These pedals are hinged at the base and are pushed down by the feet, very much like the pedals on an organ. Normally the pedals are at a 60-deg. position, and they are held there by a wire leading over a pulley to a counterweight. Springs



Plan and Front Elevation of the Maurice Farman Biplane hold all the wires taut. If the aeroplane were suddenly to tip up on the right, the right pedal would be pressed down. By this means the right side is lowered and the left side raised. When making turns, if it is found desirable to use the transverse control, then the pedal on the side to which it is desired to turn is pressed down. The controls, wires, etc., are all duplicate in this machine, to avoid any serious consequences in case of breakage of any part of the steering gear.

Tail.—The horizontal tail planes exert a considerable lifting force. There are no vertical keels. In former machines, vertical panels, "curtains," were used, but they are now eliminated.



SIDE ELEVATION OF THE MAURICE FARMAN BIPLANE

Propulsion.—In general this type is equipped with a Renault eight-cylinder 60 horse-power air-cooled motor. A Chauvière "Integrate" propeller is mounted on the cam shaft. It is 9.8 feet in diameter, 5.2 feet pitch, and revolves at 850 r.p.m. The motor is placed back of the gasoline tank, which is at the rear of the seats.

Seats.—At the center on the lower plane is placed a fusiform frame inclosed in canvas. At the front, well protected from the wind, sits the aviator. Maurice Farman was the first biplane constructor to adopt full protection from the head wind.

A passenger seat is provided at the rear of the pilot, and is also equipped with a steering gear.

Mounting.—The mounting at the front is on two rubber-tired wheels, fitted to the long curved skids by a rubber spring fastening. At the rear are two smaller wheels. The mounting is especially strong, since the skids are important members of the framework, and transmit the shock of landing over the entire structure.

Weight, Speed, Loading and Aspect Ratio.—

The total weight varies from 1,100 to 1,250 pounds. Tabuteau in his record flight made a speed of 47 miles an hour during the first two hours, and then the speed gradually increased until at the end, he was flying at 51 miles an hour. Twenty-one pounds are carried per horse-power, and 2.35 pounds per square foot of surface. The aspect ratio is 4.8 to 1.

On Tabuteau's machine, the carrying surface was increased in size by the addition of a panel on each side of the upper plane, resembling greatly the construction on the H. Farman "Type Michelin."

References.—**Quittner and Vorreiter, Zeit. für Flugtech. u. Motorluft., November 26th, 1910; Aero, October 19th, 1910, p. 313; October 26th, 1910; November 2nd, 1910, p. 350. November 23rd, 1910, p. 414; Flugsport, October 19th, 1910; Allgemiene Auto Zeitung, November 6th, 1910, p. 1; Aerophile, February 15th, 1909, p. 81; June 1st, 1910, p. 251; Gabriel, M. Zeit. für Flug. u Motor, November 26th, 1910, p. 287; Revue de l'Aviation, No. 41, p. 89; Revue Aeronautique, No. 36, p. 197; Flight, November 19th, 1910, p. 948; October 22nd, 1910, p. 862.**

10. THE GOUPY BIPLANE

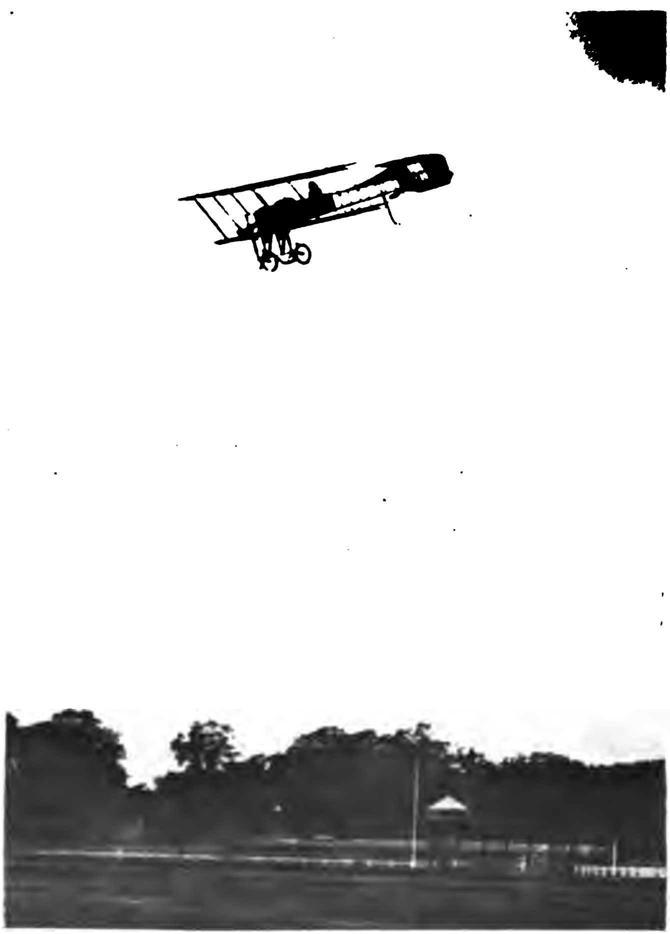
One of the first machines designed by M. Goupy was a triplane with a rear stabilizing cell, built for him by the Voisins and flown for short distances in the spring of 1908.

The Goupy biplane, built in the Blériot factory, resembles the Blériot monoplanes in all the important features of its construction with the exception that instead of one large plane, two smaller planes are used. The original Goupy (1909) was built to the plans of M. Goupy and Lieut. Calderara. It was characterized by a front horizontal rudder, which has since been abandoned, and a four-bladed propeller.

At Rheims, Ladougne on a Goupy won many prizes, and the

Goupy has often exhibited exceptional stability in strong winds.

Frame.—The central frame is of the ordinary Blériot wood and cross-wire construction. The main biplane cell is at the front and at the rear is placed a smaller cell.

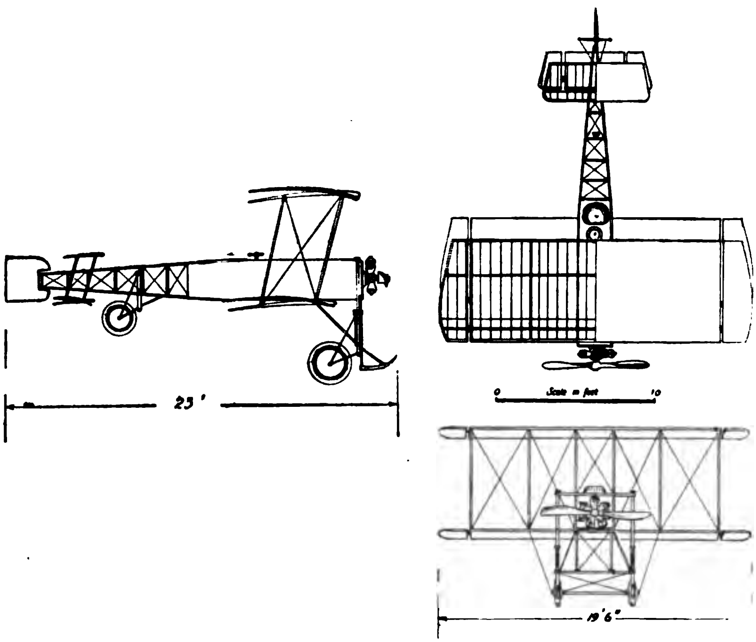


Courtesy of "Flight."

M. LADOUGNE AT DONCASTER, OCT., 1910: "VOLPLANING" ON HIS GOUPY BIPLANE

Supporting Planes.—The most distinguishing feature of this biplane is the staggering of the main planes, i. e., the upper one is placed ahead of the lower one. It is claimed that this disposition gives increased stability in "volplaning."

Both the upper and lower planes have ailerons attached at their ends, resembling very much those used on the former



PLAN AND ELEVATIONS OF THE GOUPY BIPLANE

Blériot IX. The curvature is flat, and the planes have a considerable thickness. The spread is 19½ feet, and the depth 6½ feet. The surface area is 237 square feet.

Elevation Rudder.—At the rear of the machine is a horizontal biplane tail. The lower surface of this tail is divided into three parts, the central one being fixed and the outer ones movable. These outer sections move jointly, and resemble the elevation rudder on the Blériot XI. *bis.*

A Blériot *cloche* (explained in full under the Blériot XI.) is provided for control. By pulling back on the *cloche*, the incidence of the ailerons is increased, and at the same time the rear elevation rudder is turned up, so that there is a very strong movement for ascent, the front rising and the rear descending.

Direction Rudder.—A single-surface direction rudder is placed at the rear, and is operated by movement of a steering wheel mounted on the control column. No foot lever is used. To turn to any side the wheel is turned to that side.

Transverse Control.—The ailerons are actuated by the side to side movement of the *cloche*. If the machine were suddenly tipped up on the right side then the *cloche* would be pulled over to the right thus increasing the incidence of the left ailerons and decreasing the incidence of the right ones. This pulls the machine up on the left side and down on the right, thus correcting the equilibrium.

Keels.—The fixed portion of the lower plane at the rear and the small plane above it act as keels exerting a considerable lift. There is also a small tapering vertical keel in front of the rear cell, and the two end panels of the small rear cell are "curtained" with fabric, thus giving two more vertical keels.

The *seat* for the aviator is placed in the frame at the rear of the main cell. A passenger seat is placed well in front of this, over the center of gravity.

Mounting.—The mounting is essentially on three wheels. The two at the front are mounted on the customary steel-tube, rubber-rope spring, Blériot chassis. There is a single wheel at the rear. The front chassis is also provided with two small but very strong skids.

Propulsion.—A 50 horse-power seven-cylinder Gnome rotary motor mounted at the front drives a "Perfecta" two-bladed propeller 8¼ feet in diameter and 4 feet pitch at 1,200 revolutions per minute.

Weight, Speed, Loading and Aspect Ratio.—

The total weight in flight is nearly 1,000 pounds. The speed is 45 miles per hour. Twenty pounds are lifted per horse-power, and 4.2 pounds per square foot of surface. The aspect ratio is 3 to 1.

References.—Flight, July 16th, 1910, p. 553; December 3rd, 1910, p. 991; Fachzeit. für Flugtechnik, November 13th, 1910, p. 17; L'Aerophile, July 15th, 1910, p. 317; August 1st, 1910; V. Quittner and A. Vooreiter, "Neve Flugzeuge in Paris;" Zeit. für Flug. und Motor, November 26th, 1910. Aero, November 2nd, 1910, p. 350; L'Aerophile, April 1st, 1909, p. 150.

11. THE NEALE BIPLANE

Although similar in general outline and type of construction to the Farman, this new English biplane is radically different in the method of transverse control, in the absence of any rear direction rudder, and in the structure of the surfaces. Many successful flights have been made by the Neale VII., and the odd type of transverse control used appears to work out well.

The Frame.—The framework is similar to the general wood and cross-wire main cell with outriggers now so commonly employed.

The Supporting Planes.—The planes are rectangular, and directly superposed and have an incidence of 9 degrees. They are made of one layer of fabric, sandwiched in between the flat faces of two semicircular ribs screwed together, and considerably cambered. Horizontal cross braces are used under the main spars. This construction gives great strength and is very simple and cheap. The planes have a spread of 34 feet, a depth of 6½ feet, and an area of 400 square feet.

The Elevation Rudder.—A single plane elevator in front, 24 square feet in area, and the trailing edge of the tail surface, are movable jointly, and are controlled by the front and back motion of a universally pivoted control lever (*à la* Farman). To rise, the lever is pulled in.

The Direction Rudder.—The main object in the design of this aeroplane was to construct a machine that could fly across the wind easier than most present machines, which tend to head up into the wind. Hinged to the front strut at either end of the main cell are flaps, or balancing planes called "screens." They are controlled by the side-to-side motion of the lever. These serve the double purposes of rudders and balancers. They are really brakes, and for steering act as such, merely retarding one side of the machine, while the other "skews" about. If the control lever is pulled over to the left, the left screen is pulled toward the center and thus "brakes" that side.

Transverse Control.—It was found in practice with this machine that a 5 deg. deflection of a screen sufficed for a sharp turn. If the screen on one end was sharply set at 45 deg., however, the machine was found to tip down on that end. This is due to the fact that a large mass of air is screened off suddenly from the planes, and this, with the decreased speed of this end, greatly de-

Courtesy of "Flight."

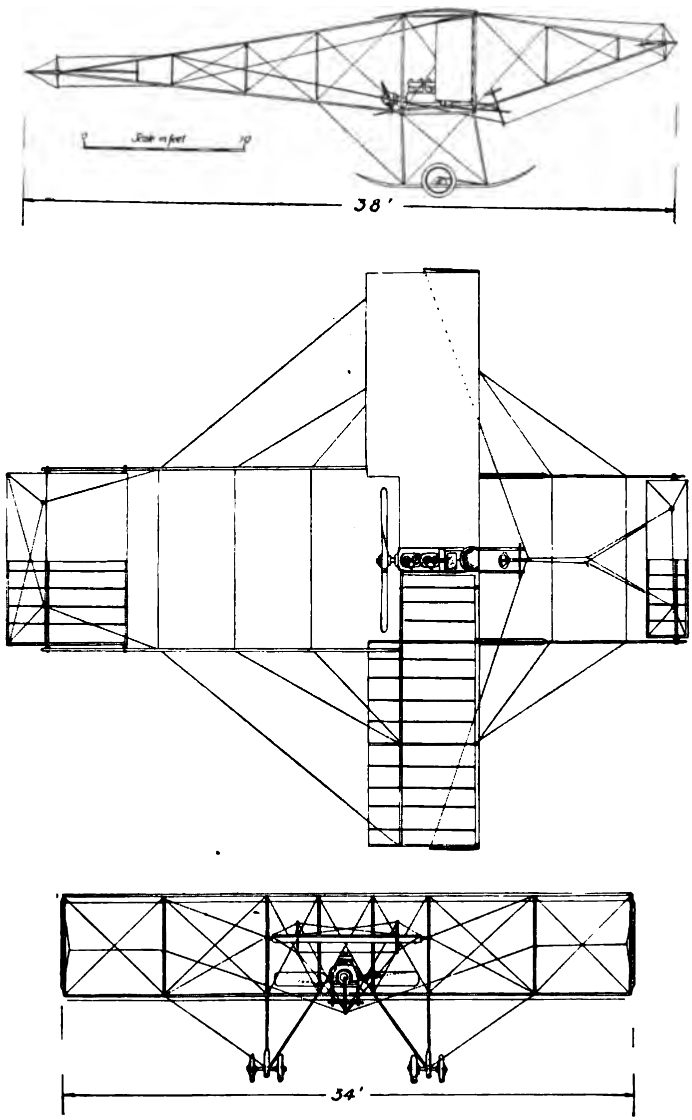
SIDE VIEW OF THE NEALE BIPLANE

creases the lift on this end. The entire success of this operation, however, depends on its suddenness. The screen must be released immediately after deflection, for if held in place air would be drawn in on the other side, and the screening action destroyed. The operation is repeated in quick succession, the required pull on the lever being quite great.

The screen rudders are 12½ square feet in area. A sudden tip down to the left would be corrected by quickly moving the lever several times to the right.

Tail.—There is a single horizontal tail surface at the rear, 52½ square feet in area and having a spread of 10½ feet.

Propulsion.—A 35 horse-power four-cylinder Green engine drives a two-bladed wooden propeller, 7 feet 3 inches in diameter



PLAN AND ELEVATIONS OF THE NEALE BIPLANE and 4 feet 1½ inches pitch, at 950 revolutions per minute. The motor and propeller are at the rear, the motor being mounted on the lower frame.

A distinctly H. Farman type wheel and skid chassis is used.

Weight, Speed, Loading and Aspect Ratio.—

The total weight is about 1,000 pounds; 28½ pounds are lifted per horse-power and 2.5 per square foot of surface. The aspect ratio is 5.2 to 1.

References.—Fachzeit. für Flugtechnik, No. 42, p. 17; Flight, October 8th, 1910, p. 813.

12. THE PAULHAN BIPLANE

The new Paulhan biplane, actively discussed in aviation circles, is remarkable only for the strength and elasticity of its structure, and the ease with which it can be packed and shipped.

M. Louis Paulhan, whose great exploits as an aeroplane pilot are well known, has here made a happy combination of a new type of construction and the customary disposition of parts in an aeroplane, that is distinctly a step in advance.

Caillé flies this type well.

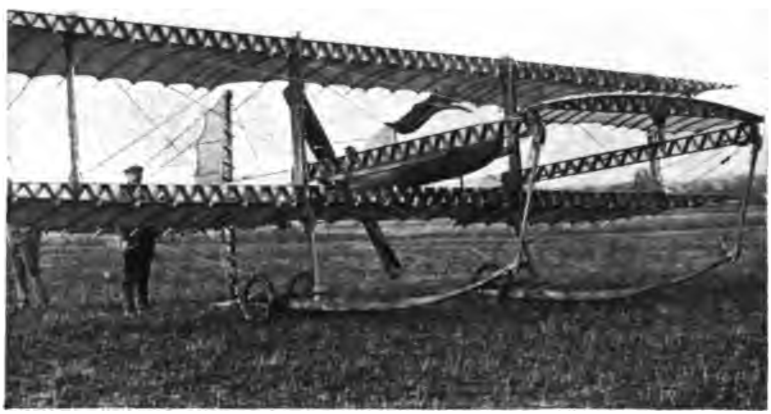
The Frame.—The frame mainly consists of two lateral girders about 6½ feet apart, placed one over the other, and two longitudinal girders, attached to the lower one. The lateral girders form the entering edge of the main planes, and to them are affixed the numerous ribs. These girders are connected by four huge wooden uprights very wide and thin, fixed by a novel leather joint.

The longitudinal girders carry the elevator at the front, and the rudder and tail at the rear. There is a total absence of cross-wires, the necessary bracing being obtained by the use of a few stout steel cables.

The girders are made of the famous Fabre built-up lattice-work, consisting of two long strips of wood connected by a line of steel triangular plates, the whole giving extremely low weight and resistance as well as great strength.

The Supporting Planes.—The ribs of the planes are very flexibly fixed to the main cross girders by an ingenious clip, which is very easy to remove or replace. In the canvas of the planes are sewn pockets corresponding to each rib. To put the covering on, these pockets are merely slipped over the ribs and the edges of the material clipped to the front girder and to the rear of each rib. This is an exceptionally practical provision. The surfaces of the planes are very smooth from front to back and are unobstructed by any cross pieces.

The planes have a spread of 40 feet, a depth of 5 feet, and a surface area of 320 square feet.



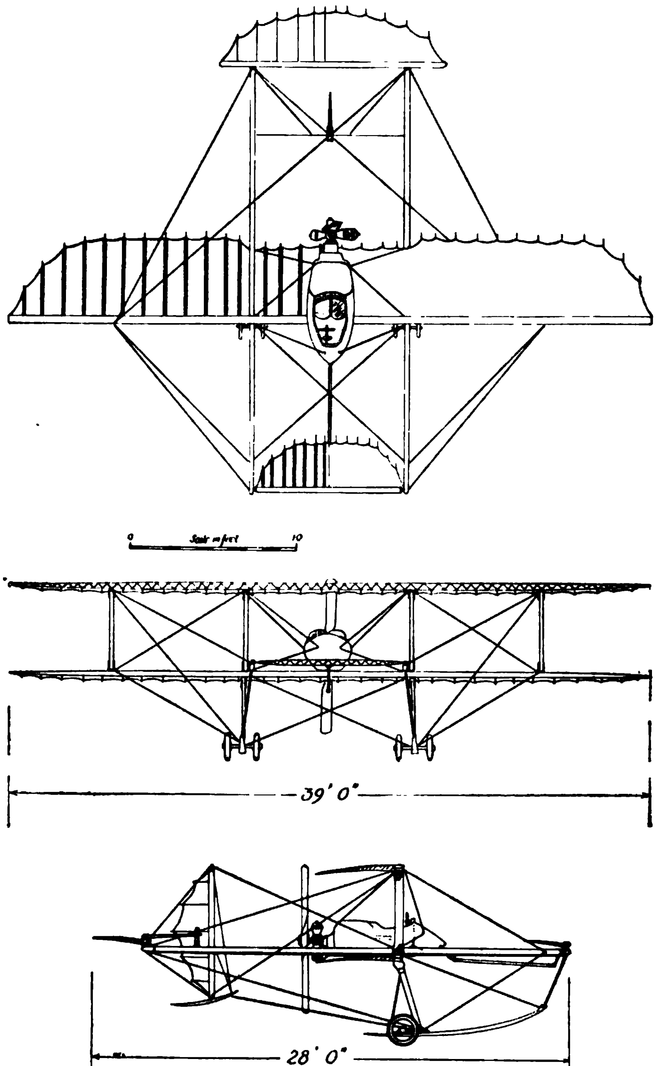
THE PAULHAN BIPLANE

M. Caillé is seated in the nacelle.

The Elevation Rudder.—The elevation rudder, at the front, is small in size and very strong. It is operated by the forward or back movement of the controlling column, as on the Curtiss and M. Farman.

The Direction Rudder.—The direction rudder is suspended rigidly by cables at the rear just in front of the horizontal *empennage.* It is actuated by the rotation of the steering wheel on the control column, clockwise for a turn to the right, etc.

Transverse Control.—The great elasticity of the planes readily permits of their being warped to preserve transverse equilibrium. This is done by the side-to-side motion of the controlling column.



Plan and Elevations of the Paulhan Biplane

A movement to the left, pulling down the rear edge of the plane at the right, etc.

Tail.—A rear horizontal tail or *empennage* is provided. It is held in place by a lever which can be moved in a slotted bar, and which is locked and unlocked by a key. This enables the incidence of this rear plane to be altered at will and made weight lifting or not, depending on the load to be carried.

Propulsion.—A 50 horse-power 7-cylinder Gnome motor, placed at the rear of the *nacelle,* drives at 1,300 r.p.m. a "Normale" wooden two-blade propeller, 8.9 feet in diameter and of variable pitch.

The Nacelle.—The seats, the steering gear, the gasoline tank, etc., are all inclosed in a fusiform body of aluminum sheeting, called the *nacelle.* This is suspended rigidly from the frame, but in no way rests on it. It is very light, affords great comfort, and is an especially desirable feature because of the ease with which the motor and propeller can be regulated as regards their adjustment and mounting.

The Mounting.—Two very long and strong skids are attached under the main lower lateral girder by heavy uprights, and extend out and up to the elevator. At a point about below the center of gravity a pair of heavy rubber-tired wheels are elastically mounted to the skids. At the rear under the direction rudder is a small skid.

Weight, Speed, Loading and Aspect Ratio.—

The total weight is 950 to 1,050 pounds. The speed is 48 to 50 miles an hour. The aspect ratio is 8 to 1. This is exceptionally high. Twenty-one pounds are carried per horse-power, and 3.28 pounds per square foot of surface.

References.—Aero, 1910, October 26th; November 2nd, p. 350; November 9th; November 16th; November 30, p. 430; "Neue Flugzeuge in Paris," Zeit. für Flugtech und Motor November 26th, 1910; Zeit. für Luftschiffahrt, No. 23, p. 14, 1910; Allge. Auto. Zeit., 1910, No. 44, p. 5; No. 46, p. 52; Flugsport, November 2nd, 1910, p. 675; Flight, October 22nd, 1910, p. 858; Fachzeit. für Flug., November 13th, 1910, p. 15; Aero. (Am.), December 10th, 1910, p. 3; Aircraft, December 10th, 1910, p. 365; L'Aero, November 10th, 1910, p. 2, No. 152.

13. THE SOMMER BIPLANE

In June, 1909, Roger Sommer purchased a biplane constructed by Henri Farman, and on July 3d he made his first flight. Scarcely a month later he held the world's record for duration of flight, having flown continuously for two and a half hours. His sudden jump into the ranks of the great aviators was unusual and showed that, after all, it was not so hard to learn to fly well. At Rheims and at Doncaster, during the fall of 1909, he won many prizes, but shortly after this gave up flying on the Farman aeroplane and proceeded to design and construct his own. On January 6th, 1910, this biplane was completed and tried out for the first time. M. Sommer at once succeeded in making three perfect flights of several kilometers each, and after three days of experimenting, a long cross-country flight was made. This aeroplane was also operated by Lindpainter and Legagneux.

On December 31st, 1910, the Sommer flew 109 miles in competition for the Michelin trophy, and later, an especially large Sommer established a passenger carrying record.

The Frame.—The materials of construction of the frame are chiefly hickory and ash, steel joints and steel tubing. The general character and appearance of the frame is somewhat similar to that on the Farman machine.

The Supporting Plane.—Two identical and directly superposed rigid planes carry the machine. The surfaces are made of rubber cloth covering wooden ribs. The sectional curvature of the surfaces is not as highly arched as on most other types, but is more nearly as in the Wright machine, a very even and gently sloping curve. The spread of the planes is 33 feet, the depth 5.2 feet, and the surface area 326 square feet.

The Direction Rudder.—The direction rudder consists of a single surface at the rear of 10 square feet area. It is operated by a foot lever, governed by the aviator. To turn to the right this lever is turned to the right, etc.

The Elevation Rudder.—At a distance of 8.25 feet in front of the main cell, and supported on framing carried down to the skids, is situated the single surface elevation rudder. This is governed by a large lever in the aviator's right hand, which when pushed out turns down the rudder, and when pulled in turns up the rudder, thus respectively lowering and raising the aeroplane.

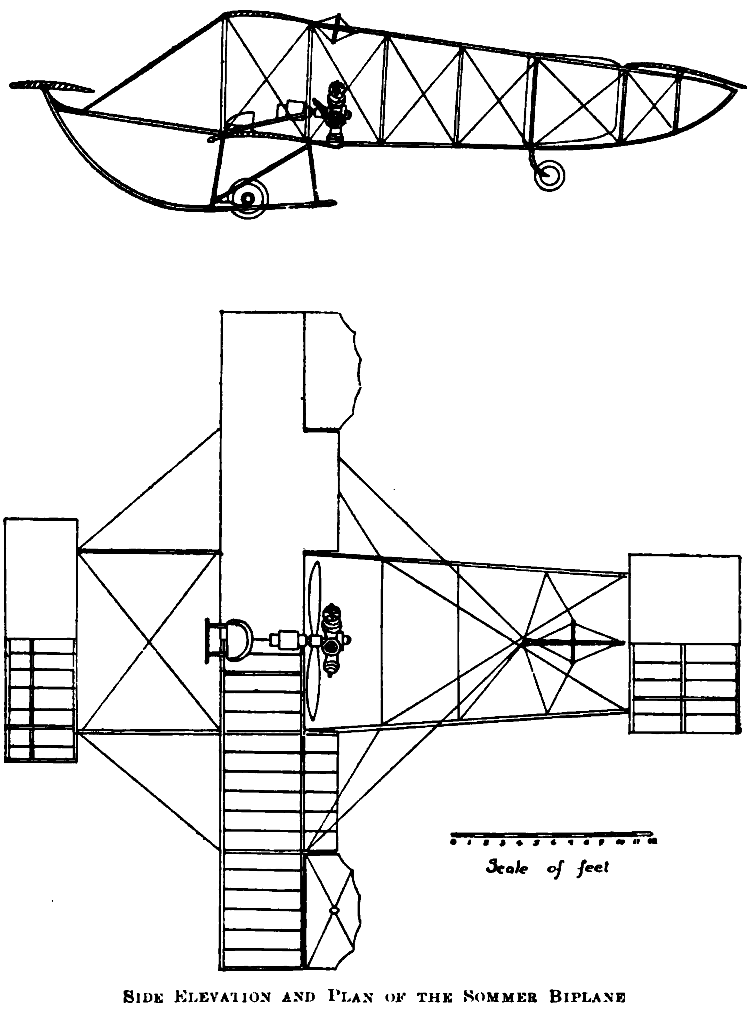
Transverse Control.—The lateral equilibrium is secured by

Photo Edwin Levick, N. Y.

THE SOMMER BIPLANE, RACING TYPE

The lower plane is cut away on either side, thus reducing the resistance and enabling the aeroplane to attain a higher speed. Paillette drove this machine with great success at Rouen, 1910.

means of two ailerons, one placed on either end, at the rear of the upper main plane. In distinction to the Farman there are no ailerons on the lower plane. The control is by side-to-side motion of the large lever exactly as on the H. Farman.

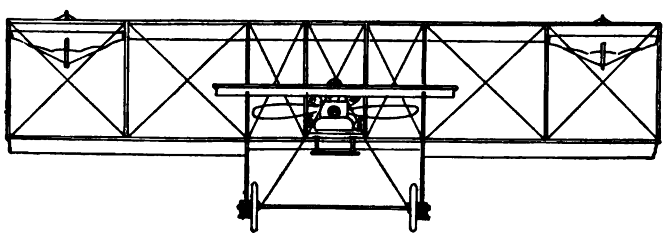


SIDE ELEVATION AND PLAN OF THE SOMMER BIPLANE

Keels.—A single horizontal plane of 55 square feet area and of very light construction is placed at the rear and steadies the machine longitudinally. This plane is movable, although it does not act as a rudder. A lever at the right hand of the aviator, which automatically "locks," enables the angle of incidence of this surface to be varied at will, thus increasing the attainable stability.

Propulsion.—A 50 horse-power Gnome rotary air-cooled 7-cylinder motor, placed at the rear of the main cell, drives direct a Chauviere wooden propeller of 7 feet diameter and 5.2 feet pitch at 1,200 r.p.m.

The Seat for the aviator is fitted more comfortably than in



FRONT ELEVATION OF THE SOMMER

other aeroplanes, and is placed on the front of the lower plane at the center.

The Mounting consists of a combination of two large wheels at the front and two smaller ones at the rear. The front wheels are attached by rubber springs to two skids, built under the frame. The skids themselves are attached to the main cell by uprights, the joints being made of a springy sheet of metal bolted to the framing. This adds still further to the extremely springy character of the mounting.

Weight, Speed, Loading and Aspect Ratio.—

The total weight varies from 800 to 900 pounds; the speed is 46 miles per hour; 16 pounds are lifted per horse-power, and 2.76 pounds carried per square foot of surface. The aspect ratio is 6.35 to 1.

Recent Alterations.—For racing purposes the Sommer has recently been altered. The two end panels of the lower surface have been eliminated, very much as on some of the Farman machines. This reduces the area of surface to 256 square feet, and makes the loading 3.25 pounds per square foot.

References.—Aerophile, v. 18, p. 61, February 1st, 1910.

14. THE VOISIN BIPLANE (1909)

The Voisin brothers began their activity as constructors of aeroplanes as early as 1905, when they constructed gliders for both M. Archdeacon and M. Blériot. These gliders were successfully operated over water, being towed at high speed and lifted from the water surface by motor boats. In 1906 the Voisins built a motor machine to the design of a young sculptor, the late M. Delagrange, and subsequently after making a few changes in the design, built a machine for M. Henri Farman which was the first truly successful aeroplane in Europe. The design of this type remained substantially the same, except for the addition of some vertical keels. This type was formerly very extensively used abroad, over one hundred having been manufactured. It is not so widely used now.

The Frame.—The frame is made of ash with steel joints and several parts of steel tubing. It consists essentially of a large box cell mounted on a central chassis, and a smaller box cell attached to it at the rear. The central chassis is really a unit in itself, and carries the wheel mounting, the motor, the seat, and at the front, the elevation rudder.

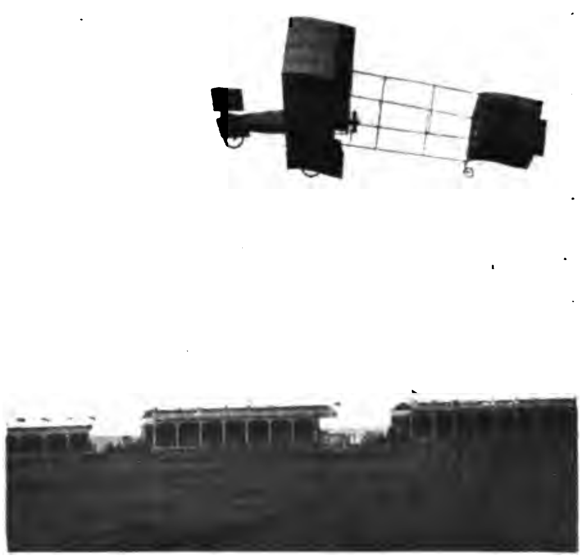
The Supporting Planes.—The main supporting planes are two in number, identical and directly superposed. They are made of Continental cloth stretched over ash ribs. Their shape is rectangular. The spread is 37.8 feet, the depth 6.56 feet, and the area 496 square feet.

The Direction Rudder.—A single surface of 25 square feet area placed in the center of the rear cells is used for directing the machine. It is operated by a steering wheel and cables as on a boat.

The Elevation Rudder.—The elevation rudder consists of a single surface of 41 square feet area situated at the front end of the central chassis. It is governed by a lever system attached to the axis of the steering wheel. By pushing out on the steering wheel the rudder's inclination with the line of flight is reduced and the machine descends. By pulling in, the machine is caused to ascend.

Transverse Control.—There is no controlling apparatus for the lateral equilibrium in this type.

Keels.—The two horizontal surfaces of the rear cell about 130 square feet area act as keels to stabilize the machine longitudinally. For steadying the machine transversely and for keeping it to its

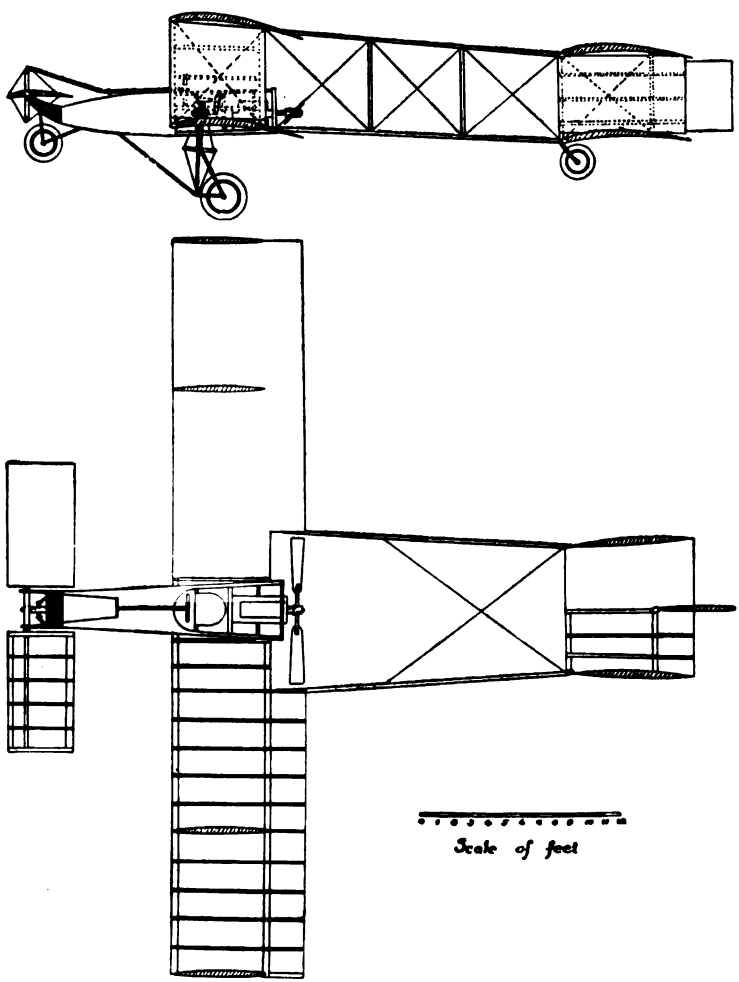


BUNAU-VARILLA ON A VOISIN AT RHEIMS (1909)

course, there are provided six vertical surfaces (two vertical walls of the rear cell and four vertical partitions between the two main supporting planes).

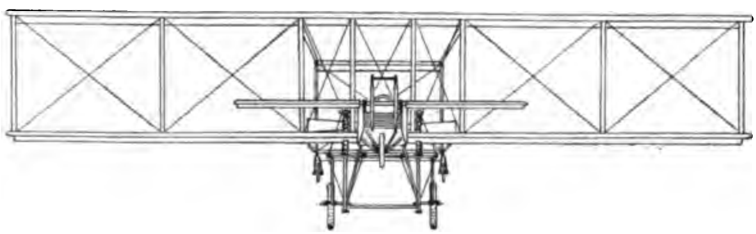
Propulsion.—A 50-55 horse-power motor, placed on the rear of the central chassis, and of the main planes, drives direct a two-bladed metal propeller, 7.6 feet in diameter and 4.6 feet pitch, at 1,200 r.p.m. Several types of motors have been used.

The Seat is placed on the central chassis in front of the motor and just back of the front edge of the planes.

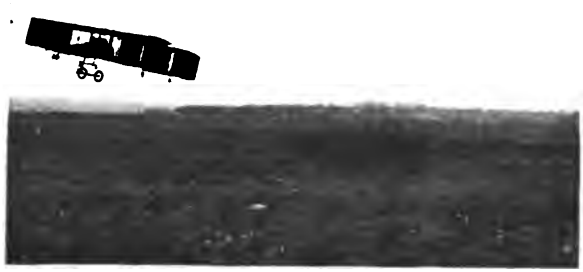


SIDE ELEVATION AND PLAN OF THE CELLULAR VOISIN (1909)

The Mounting is on two large wheels fitted with coiled spring shock absorbers at the front and two smaller wheels at the rear. To avoid any disastrous results if the machine should land too much



FRONT ELEVATION OF THE CELLULAR VOISIN



A CELLULAR VOISIN MAKING A TURN

"head on" a small wheel is fitted to the front end of the chassis directly under the elevation rudder.

Weight, Speed, Loading and Aspect Ratio.—

The total weight is from 1,100 to 1,250 pounds; the speed is 35 miles per hour; 23 pounds are lifted per horse-power and 2.37

pounds per square foot of surface. The aspect ratio is 5.75 to 1.

References.—Aeronautical Jour., v. 12, No. 46; v. 13, p. 60; Aerophile, v. 15, p. 232; v. 16, p. 38; v. 17, p. 488; Aeronautics (Brit.), v. 1, pp. 11, 18; v. 2, p. 20; SCI. AMERICAN, v. 97, p. 292; v. 98, p. 92; Locomocion Aerea, v. 1, p. 78; Boll. Soc. Aer. Ital., v. 6, p. 288; Flight, v. 1, pp. 19, 360, 485, 505; La. Tech. Moderne No. 1, p. 5; Soc. des Ing. Civ., v. 2 (1908), p. 13; Zeit. Ver. Deut. Ing., v. 52, p. 956; Vorreiter A, "Motor Flugapparate"; Encyl. d'Av., v. 1, p. 19; Genie Civil, v. 55, p. 341.

15. THE VOISIN BIPLANE (TRACTOR SCREW TYPE)

This machine, built by the Voisins and first experimented with in the late part of 1909, embodied several totally new departures in the construction of biplanes, but had little success. The Goupy and the Breguet, aeroplanes of this type, however, have been flown with great ease.

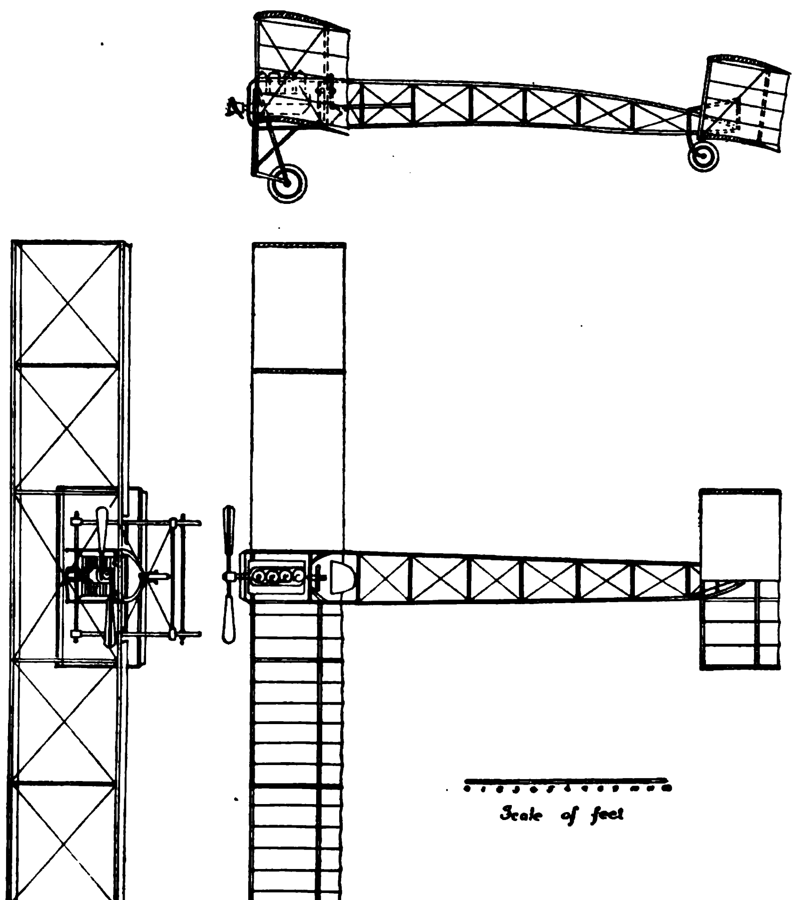
The Frame.—In this type the central chassis extended far out to the rear. At the front were situated the motor and the propeller, and directly behind the propeller was the main cell. At the extreme rear was an auxiliary cell. Ash, steel joints and steel tubing were used throughout.

The Supporting Planes.—The two carrying planes, placed at the front on the central chassis, were identical and superposed directly. Their spread was 37 feet, the depth 5 feet, and the area 370 square feet.

The Direction Rudder and the Elevation Rudder.—The rear box cell was pivoted on a universal joint, and capable of being moved up and down or to either side. It consisted of two horizontal surfaces about 80 square feet in area and two vertical surfaces 50 square feet in area. The vertical surfaces acted as the direction rudder, when the cell was moved from side to side. The horizontal surfaces served to control the elevation when the cell was moved up or down. The movement of the cell was controlled by cables leading to a large steering wheel in front of the aviator. To turn to the right, the cell was turned toward the right. To ascend, the inclination of the cell relative to the line of flight was decreased, the leverage desired being opposite in nature to that of a front elevation rudder.

Transverse Control.—There was no transverse control in this type.

Keels.—Four vertical partitions were placed between the two main planes, as in the other type of Voisin biplane.



PLAN AND ELEVATIONS OF THE EXPERIMENTAL "TRACTOR SCREW" TYPE VOISIN

The propeller at the front pulled the machine.

Propulsion.—A 40 horse-power 4-cylinder Voisin motor placed at the front end of the chassis drove direct a two-bladed metal propeller of 7.2 feet diameter and 4 feet pitch at 1,300 r.p.m.

The Seat was situated on the central frame at the rear of the main cell.

The Mounting was on two large rubber-tired wheels in front, fitted with shock-absorbing springs and a single wheel at the rear.

A CLOSE VIEW OF A CELLULAR VOISIN

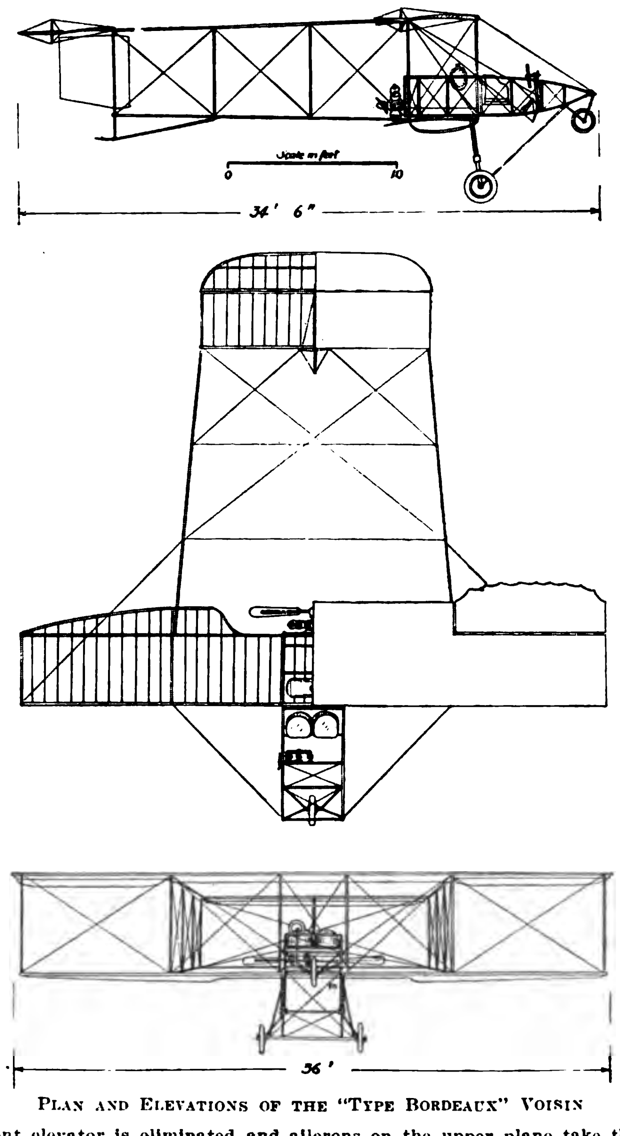
Weight, Speed, Loading and Aspect Ratio.—

The total weight was from 800 to 950 pounds; the speed was said to be 50 miles per hour; 19 pounds were lifted per horse-power, and 2.36 pounds carried per square foot of surface. The aspect ratio was 7.1 to 1.

References.—Aerophile, v. 17, pp. 441, 485; Aeronautics, v. 5, p. 200; Fachzeit. fur Flugtech., No. 39, Oct., 1909; Aero., v. 1, p. 347; Genie Civil, v. 55, p. 341.

16. THE VOISIN BIPLANE (TYPE "BORDEAUX")

Although still used abroad, the old Voisin type has recently been replaced by the type "Bordeaux," altogether different from the old type in control, disposition of parts, and structure. The front elevator and the vertical "curtains" are entirely eliminated.



PLAN AND ELEVATIONS OF THE "TYPE BORDEAUX" VOISIN

The front elevator is eliminated and ailerons on the upper plane take the place of the cellular partitions.

The type "Bordeaux" has lately had many conspicuous successes abroad, especially in the hands of Metrot, Bregi, and Bielovucie. The latter made his brilliant Paris-Bordeaux flight on this type.

The type "Bordeaux Militaire," two-seated and equipped with double controlling systems, promises to be one of the most practical of present day biplanes.

The Frame.—Steel tubing is very largely used in the framework, only the ribs and part of the central *fuselage* being made of wood. The main cell carries the usual chassis of steel tubing and *fuselage* at the center. The outriggers to the rear are also very much as on the old Voisin type.

The Supporting Planes.—The planes are of the same span, but slightly different in shape. The upper one alone carries ailerons. The structure of the surfaces is the familiar wooden rib, covered over and under with fabric, the longitudinal spars being of steel tubing. The spread is 36 feet, the depth 6½ feet, and the surface area 395 square feet.

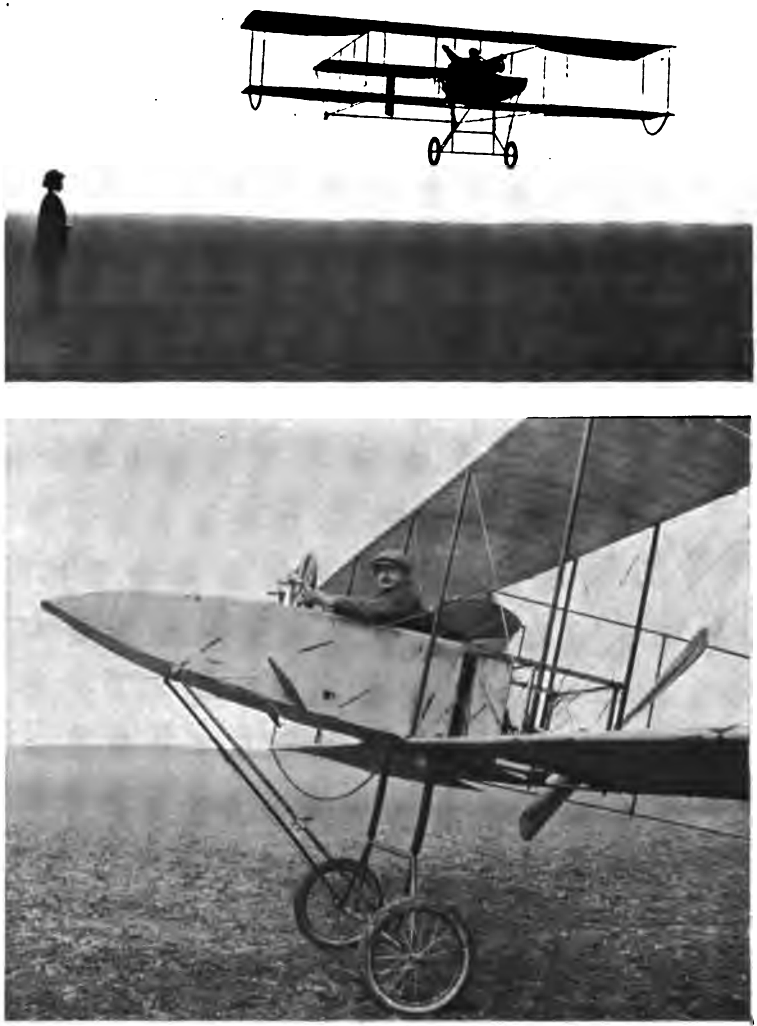
Elevation Rudder.—At the rear, back of the horizontal tail, and forming its trailing edge, is the single-surface elevator, 12½ feet wide and 2½ feet deep. This is operated by the forward and back motion of the controlling column.

Direction Rudder.—Under the horizontal tail at the rear is the single-surface direction rudder, which is turned by the movement of the steering wheel fixed on the controlling columns.

Transverse Control.—At the rear ends of the upper plane are hinged ailerons, 2½ feet chord and 9 2/3 feet wide, which hang down loose when the machine is standing still, and fly out in the air stream when in flight. They are controlled by foot pedals very much as on the M. Farman, excepting that the counterweights are not used.

The two controlling systems installed for the type "militaire" are precisely duplicates of each other.

The Tail.—The rear horizontal tail surface is placed at a considerable angle of incidence, and exerts an appreciable lift. It is 4½ feet deep and 12½ feet wide.

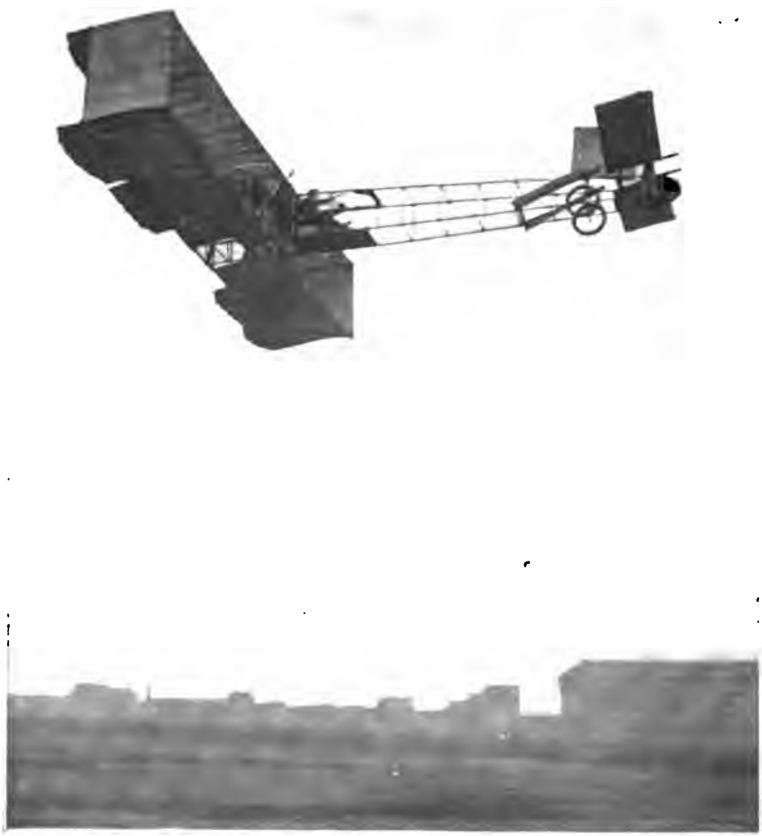


TWO VIEWS OF THE VOISIN (TYPE "BORDEAUX")

The engine is placed very nearly at the center and two sets of steering gear are provided

Propulsion.—At the rear of the central *fuselage* is mounted the motor, which must be of 55 horse-power and weigh less than 440 pounds. E. N. V. 60 horse-power and Gnome motors are largely used. A Voisin two-bladed steel and aluminum propeller, driven at 1,100 r.p.m. and 8.2 feet in diameter, is used.

Mounting.—The mounting is on a steel-tube chassis fitted with two large wheels and coiled spring shock absorbers, under the front



THE VOISIN (FRONT CONTROL, 1911)

of the cell, a small wheel on the nose of the *fuselage* as a special protection when landing, and two skids at the rear.

Seats.—Two seats side by side are built into the *fuselage* just in front of the main cell. They are exceptionally well placed, and enable the pilot to have a clear view.

The entire machine presents a very simple and finished appearance.

Weight, Speed, Loading and Aspect Ratio.—

The speed is nearly 51 miles per hour. The aspect ratio is 5.6 to 1. The weight varies from 1,300 to 1,550 pounds with full

THE VOISIN (FRONT CONTROL, 1911)

load. Twenty-eight pounds are lifted per horse-power, and 3.14 pounds per square foot of surface.

An added departure in this type is the enlargement of the carrying surface by the addition of a panel on either end of the upper plane, as on the M. Farman of Tabuteau, the Type Michelin, etc.

References.—Allge. Auto. Zeit., No. 42, p. 36; No. 43, p. 3, 1910; Aero, 1910, November 2nd, p. 350; November 30th, p. 432; Fachzeit. für Flugtech., November 13th, 1910, p. 17; Aerophile, 1910, July 15th, p. 318; September 15th, p. 411; Flugsport, October 19th, 1910; Zeit. für Flugtech. u Motor., November 26th, 1910; Flight, 1910, June 25th, p. 486; October 22nd, p. 861.

17. VOISIN BIPLANE (FRONT CONTROL, 1911)

MM. Voisin Frères have constructed a type of biplane, characterized by the absence of a tail and the grouping of the elevation and direction rudders at the front, carried by a long central *fuselage*. This *fuselage* is attached at the rear to the main biplane cell.

The motor is a 50 horse-power Rossel-Peugeot, and drives direct a two-bladed metal Voisin propeller, at the rear of the supporting planes.

The lateral stability is maintained by means of ailerons operated exactly as on the Voisin (Type Bordeaux).

The main planes have a span of 39 feet, a chord of 7 feet, and an area of 380 square feet.

The mounting is on four wheels, two at the front and two at the rear, fitted with springs.

The aviator sits in front of the main planes in the *fuselage*, and commands a clear view of the rudders and of his surroundings.

This type is experimental, but it has displayed good stability and speed, and rises off the ground very quickly.

18. THE WRIGHT BIPLANE (1909)

As early as 1903 after exhaustive experiments in gliding Wilbur and Orville Wright made flights in a motor-driven aeroplane differing little from their present well-known type. The first public flights of the Wrights were made in September, 1908, when Orville Wright, at Fort Meyer, and Wilbur Wright, at Le Mans, France, astonished the world with their consummate skill. On December 31st, 1908, the Michelin prize was won for the first time by Wilbur Wright, who on that day flew for 2 hours and 18 minutes. The Wright machine to-day holds no great record except altitude, but the flights of Wilbur Wright at New York in October, 1909, and those of Orville Wright at Fort Meyer in July, 1909, are among the most difficult as yet negotiated. Among the biplanes the Wright is almost twice as efficient in power consumption as any other type.

Many machines of the Wright type are being flown in France, Germany, Austria, Italy, and England, notably by Count Lambert and M. Tissandier in France, Capt. Englehardt in Germany, and

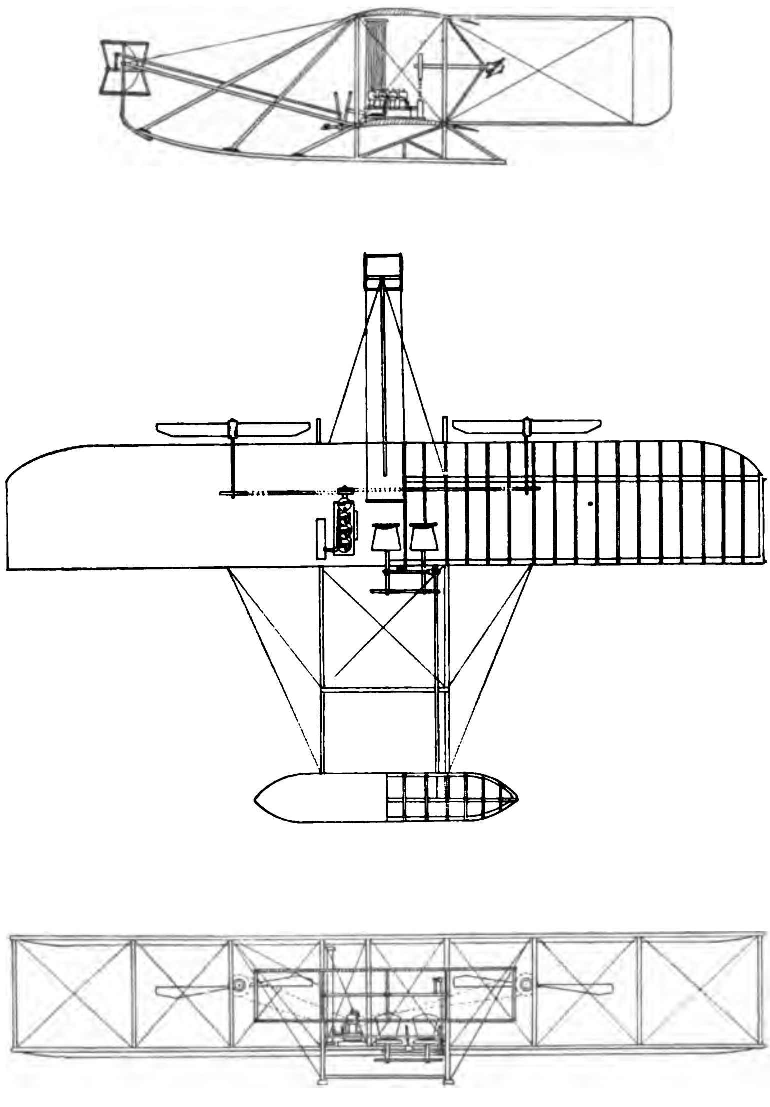
Lieut. Calderera in Italy. In this country the Wright machine has been widely used, by Messrs. Coffyn, La Chapelle, Hoxsey, Brookins. and Johnstone, as well as the Wrights themselves.

The altitude record is held by the Wright machine, the late Arch. Hoxsey having mounted to the height of 11,400 feet.

ORVILLE WRIGHT AND LIEUT. LAHM FLYING IN THE GOVERNMENT ENDURANCE TEST AT FORT MYER, VA., ON JULY 27TH, 1909

The old 1909 Wright, although at present almost entirely discarded, was a type that should not be forgotten.

The Frame.—Clear spruce and ash were used throughout the frame, which is very solidly but very simply built. The cross wires were of steel and made to fit exactly. All exposed parts of the frame were painted with an aluminum mixture.



THE 1909 WRIGHT "MODEL A." PLAN AND ELEVATIONS

The Supporting Planes.—Two identical and superposed surfaces made of canvas stretched over and under wooden ribs, supported the machine in the air. Their curvature was somewhat flatter than the usual one used, and the surfaces were 3 inches thick near the center. These planes were 6 feet apart; they had a spread of 41 feet, a depth of 6.56 feet, and an area of 538 square feet.

The Elevation Rudder.—In the 1909 Wright biplane the elevation rudder was so constructed that when elevated it was automatically warped concavely on the under side, and when depressed curved in the opposite way. This materially added to the rudder's force. It was double surfaced, 70 square feet in area, and placed well out in front, being supported mainly on framework, of which the mounting skids formed a part. At present the elevation rudder consists of a single surface at the rear. This rudder was governed by a lever in the aviator's left hand. To rise, the aviator pulled the lever toward him. This motion was formerly transmitted to the rudder mechanism by a long wooden connecting rod, causing the rudder to be turned upward to the line of flight, and consequently causing the machine to rise. To descend, the aviator pushed this lever away from him. At present the same control is used, but it is transmitted by wires to the rear.

The Direction Rudder.—The direction rudder was placed in the rear, on the center line, and consisted, as it does now, of two identical vertical surfaces of 23 square feet area. This rudder was governed by the lever in the aviator's right hand. To turn to the left the lever was pushed out, while to turn to the right it was pulled in. But this motion was very rarely used, since the side-to-side motion of this lever also controlled the warping, and the two motions in this type were very intimately connected.

Transverse Control.—The famous warping device was used by the Wrights for the preservation of lateral balance, and for artificial inclination when making turns. The rear vertical panel of the main cell was divided into three sections. The central one was solidly braced and extended either side of the center to the second strut from each end. From these struts the rear horizontal cross pieces of the planes were merely hinged instead of being continued portions of the cross piece at the center, and the two end vertical panels on either end were not cross braced. These two rear end sections of the cell were therefore movable. The entire front of the machine, as well as the actual ribs inside the surfaces, however, was perfectly rigid, there being no helical torsion of the ribs themselves as commonly supposed. Cables connected these two sections of the planes together and led to the lever in the aviator's right hand. The operation was as follows: If the machine suddenly

De Lambert on a Wright (1909)

dipped down on the right end, for example, then the lever was moved to the left side. This action pulled down the rear right ends of the surfaces, and at the same time pulled up the rear left ends of the surfaces. This caused an increase of incident angle of the outer end of the plane on the side depressed, and a decrease of incident angle on the opposite side; the consequent increase of lift on the depressed side and decrease of lift on the raised side righted the machine at once. But throughout this process the entire front face of the cell, as well as the rear central section, remained perfectly rigid in every sense.

For turning to the left for example, it is evident that if this same lever were moved in a circular arc, outward and to the left (very much as a trace of the desired turn) then not only would the surfaces be warped, so as to raise the right end, but also the direction rudder set to give the desired change of direction, and the consequent action was prompt and very efficacious.

In actual practice the direction rudder and transverse control of the Wright machine are almost never worked separately.

Keels.—There were no fixed keels on the Wright 1909 biplane. A small pivoted vertical surface was placed in front to indicate any change in direction of the relative air current.

Propulsion.—A 25-28 horse-power 4-cylinder Wright motor drove by chains, in opposite directions, two two-bladed propellers. These propellers were made of wood, and were placed at the rear of the main cell, one on either side of the center. They rotated at 400 r.p.m., and were 8.5 feet in diameter and of 9-foot pitch.

Seats were provided for two, the outer one for the aviator. They were placed on the front edge of the lower plane to the side of the motor.

Formerly the *Mounting* was on skids only. When starting the machine was placed on a small truck and run over a rail on the ground. At present wheels are used.

Weight, Speed, Loading and Aspect Ratio.—

The total weight was from 1,050 to 1,150 pounds; the speed is 40 miles per hour; 41 pounds were lifted per horse-power of the motor, and 2.05 pounds per square foot of surface. The aspect ratio was 6.25 to 1.

Alterations.—The dimensions of the United States Signal Corps' machine and that built by the Aerial Company of France differed in that the spread was reduced to 36 feet and the surface area to 490 square feet.

In the French Wright machines of Count Lambert and M. Tissandier, the aviator sits next to the motor. When instructing these two men at Pau in the winter of 1909, Mr. Wilbur Wright had fitted to the machine an extra lever (to control the elevation rudder) on the right side of the passenger who sat next to the motor.

THE WRIGHT MACHINE AT WASHINGTON (1909)
The old derrick and starting rail are shown in the foreground.

The position of the levers for the passenger was therefore the reverse of the usual one, the lever controlling the direction rudder and warping being at the left hand. Tissandier and De Lambert having learned to operate the machine with this disposition have never changed it. But they in turn have become the instructors of many purchasers of Wright machines, and since their pupils occupy the outside seat, they are taught to control in the normal manner.

References.—Aeronautics, v. 3, Nos. 3 and 4, v. 5, p. 170; Sci. American, v. 99, p. 140, 209; Aeronautical Jour., v. 12, p. 114; Zeit. für Luftschiff, v. 13, p. 6; Aerophile, v. 16, p. 470; v. 17, p. 488; Boll. Soc. Aer. Ital., v. 4, p. 410; v. 6, p. "88; Locomocion Aerea, v. 1, p. 78; La Tech. Moderne, No. 1, p. 5; Encyl. d'Av., v. 1, p. 19; Am. Machinist, v. 31 (2), p. 473; Century, v. 76, p. 641; Peyrey, F., "Les Hommes Oiseaux"; Bracke, A., "Const. de l'Aerop. Wright"; Vorreiter, A., "Motor Flugapparate"; Genie Civil, v. 55, p. 342; Zeit. Ver. Deut. Ing., v. 53, p. 1098.

19. THE WRIGHT BIPLANE (MODEL R)

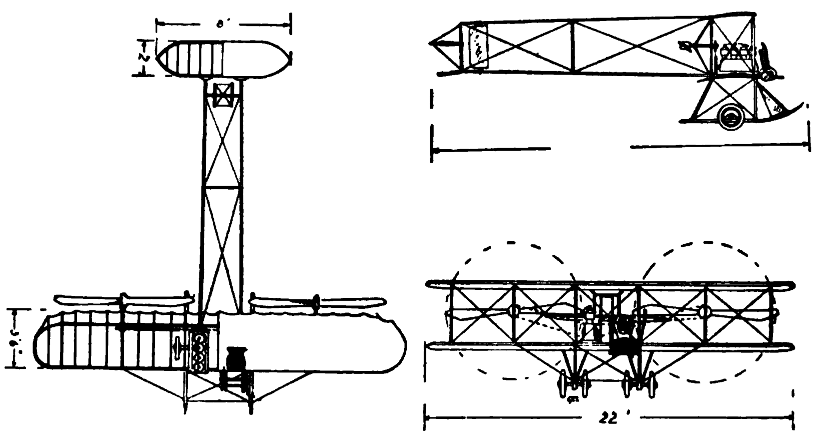
Probably the most interesting aeroplane that has been brought out during 1910 is the small Wright "roadster," with its miniature

THE SPECIAL WRIGHT GORDON BENNETT RACER
Orville Wright is at the front testing the engine. The propellers are in motion.

biplane cell, and its huge propellers spanning almost the entire machine. This latest speed and reliability product of the Dayton inventors has excited a very lively interest, and without doubt points the way to many of the improvements that the future holds. A machine of this type, but fitted with a 60 horse-power 8-cylinder motor and very much smaller in size, was to be driven in the 1910 Gordon-Bennett Race by Brookins, and there is little doubt, with the phenomenal speed it had already displayed, that it would have won this race from Grahame-White had the unfortunate failure of the engine not occurred.

The regular 30 horse-power type of this machine has, however, proved itself a very good one. Both in speed and in its remarkable ability to gain great altitude, this machine in the hands of Ogilvie, Brookins, and the unfortunate Johnstone, has exhibited far better qualities than many foreign machines using almost twice the horse-power. The speed with which this type can "climb" is exceptional.

The Frame.—The framework follows closely the regulation Wright lines, the outriggers and rudders being similar to the 1910



PLAN AND ELEVATIONS OF THE WRIGHT MODEL R, "ROADSTER"
Note the area swept through by the propellers in comparison to the span.

Wright. The skid and wheel mounting, however, is quite different in appearance, although identical in principle.

The Supporting Planes.—The two identical planes are the smallest yet used on an aeroplane. The shape and curvature is as on the other Wright machines, excepting that they project quite a distance out beyond the end panels of the cell. The planes have a spread of 26½ feet and a chord of 3 feet 7 inches. The total area is 180 square feet. On the Gordon-Bennett racer the spread was 21½ feet and the surface only 145 square feet.

The Elevation Rudder.—A single horizontal surface at the rear serves as the elevator, exactly as on the large 1911 Wright biplanes. This surface is 8 feet by 2 feet, and is operated by the new-type Wright control lever placed either on the left or right of the aviator. W. Wright and Brookins, for example, are accustomed to opposite positions. The control lever is mounted on a shaft, and to

THE 60 HORSE-POWER MOTOR OF THE SMALL WRIGHT RACER, AND THE CHAIN DRIVE TO THE PROPELLERS

it is fixed a drum about 6 inches in diameter. The wires for the control are fastened to this drum by short chains, and are thus moved by the lever, a forward movement causing descent, etc.

The Direction Rudder.—The usual biplane direction rudder is used and is operated by the movement of the lever opposite to the elevation rudder lever. By moving this lever and its drum and chain connection forward and back the combination warping and rudder movement is effected, the rudder tending always to steer the machine to the depressed side. The drum upon which the direction rudder wires are attached is pressed against the lever by a spring and is thus moved with it. In addition, the handle at the top of the lever is made movable and is so connected to the drum that by moving it from side to side, the direction rudder can be operated alone and independently of the warping.

The Transverse Control.—The transverse control is by means of warping, as usual, but the control mechanism, although similar to that used on all the Wright machines at present, is radically different from the old 1909 type.

On the same shaft upon which is mounted the direction-rudder lever and drum is another drum fitted with chains leading to the wires controlling the warping, but in no way connected with the drum to which the direction rudder is attached, except by the spring device as already noted. The operation of the warping is done by the forward and back motion of this lever, and no more by a side-to-side motion as formerly. There is no tail other than the rudders, which in their normal position act as a tail. Two small vertical surfaces on the skid frame at the front are used.

Propulsion.—A regulation 30 horse-power Wright motor is installed, and drives, as usual, by chains, two wooden propellers, 8 feet 6 inches in diameter, at 450 r.p.m. In the "racer" an eight-cylinder 60 horse-power motor drove the propellers at 525 r.p.m. The detail of the propelling mechanism is exactly as on other Wright types.

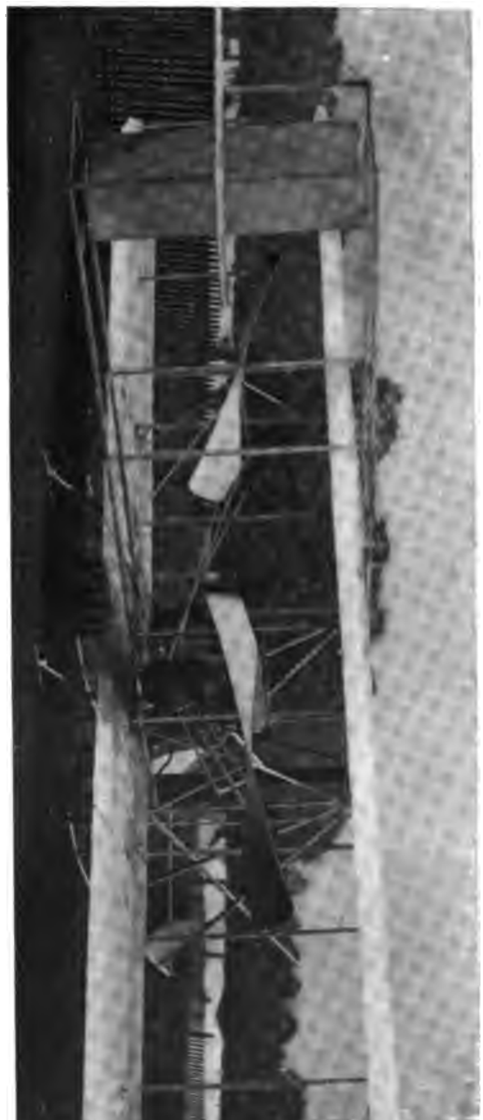
Mounting.—The mounting is on two short skids built down from the lower plane. On each skid is mounted a pair of wheels, the axle being fastened to the skid by a rubber spring arrangement.

On the "racer" two additional wheels were placed in front, making six in all. The chassis on the "racer" appears to have been too weak, but on the "roadster" it works well.

The single *Seat* for the pilot is placed as usual to the left of the motor.

Weight, Speed, Loading and Aspect Ratio.—

The total weight in flight is about 760 pounds, the machine weighing 585 pounds unmounted. The speed of the "racer" has



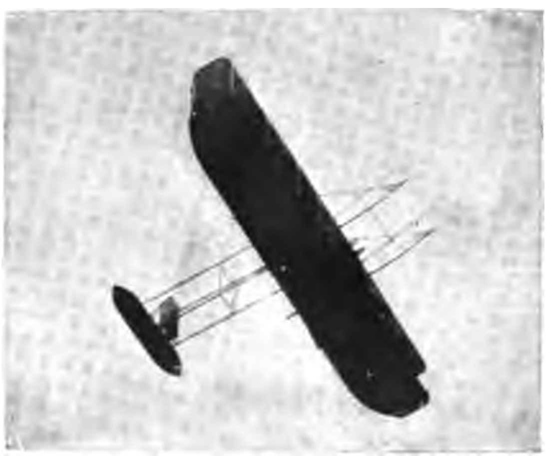
THE MODEL B WRIGHT
Rear view, showing the propellers and rudders.

A Detail View of the Model B, From in Front, Showing the Chassis, Seats, Motor and Control Levers been timed by the author at 67.5 miles an hour, and that of the "roadster" at 54.5 miles an hour. Wilbur Wright has stated that even higher speed had been obtained. The pounds carried per horse-power by the "roadster" are 25.4, and 14.3 by the "racer"; the pounds per square foot are 4.20 for the "roadster" and 5.92 for the "racer," the highest loading ever carried on an aeroplane up to the present. The aspect ratio is 7.4 to 1.

References.—Aeronautics, December, 1910, p. 192; Aircraft, December, 1910, p. 363.

20. THE WRIGHT BIPLANE (1911) MODEL B

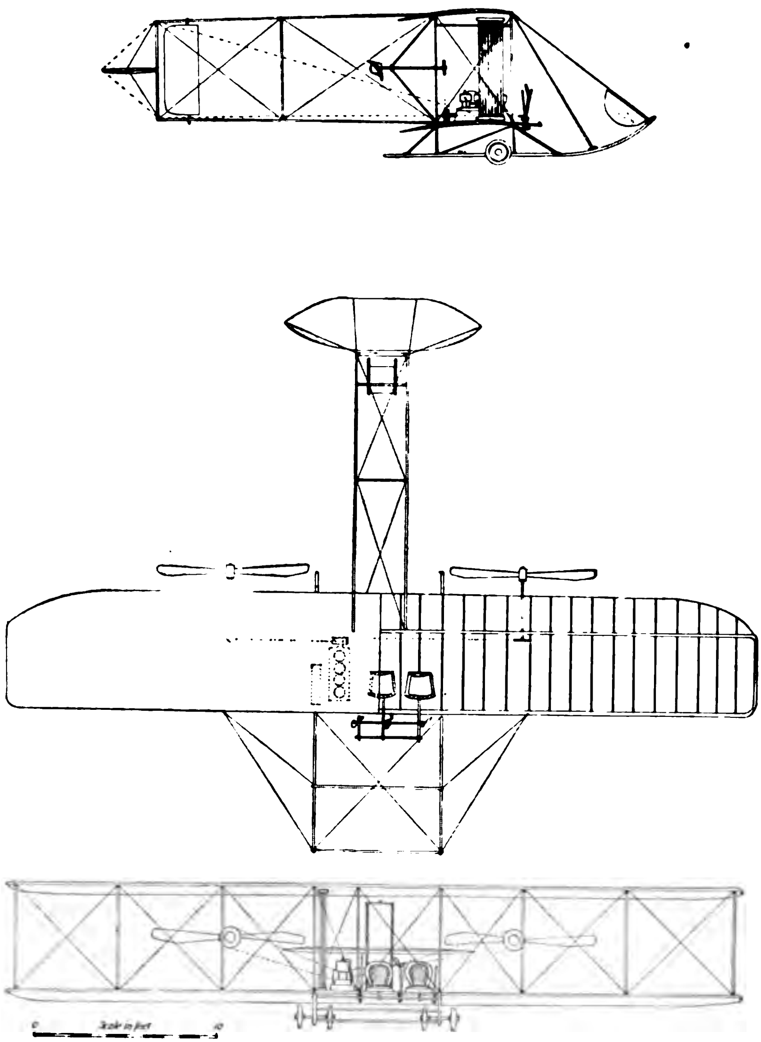
The new Wright passenger biplanes differ from the 1909 type in that the front elevation rudder is eliminated entirely; in its



MODEL B IN FLIGHT

This photograph shows the shape of the planes and rudders as viewed from underneath.

place a small single surface is carried at the rear, and either warped up or down or turned for elevation control, depending on the manner in which it is attached to the frame. The entire machine is resembled closely in appearance by the new "roadster."



Plan and Elevation of the Wright Biplane, Model B

The type of construction and the disposition of the motor, propellers, etc., is practically the same as on the older types.

The chassis is now fitted with wheels attached to the skids by rubber springs.

The control is by means of the new "breaking" lever system (see p. 288).

The new aeroplanes are smaller and faster than the old ones. The spread is reduced to 39 feet, the depth to 6¼ feet and the area to 440 square feet. A 30 horse-power motor is used as usual. Thirty-seven pounds are lifted per horse-power and 2.5 pounds per square foot of surface. The aspect ratio is 6.3 to 1.

On some of the Wright biplanes in Europe, Gnome motors and single propellers have been installed.

PART III.

COMPARISON OF THE TYPES—CONTROLLING SYSTEMS—ACCIDENTS—THE FUTURE

CHAPTER XII.

COMPARISON OF THE PROMINENT TYPES

In comparing the successful types of aeroplanes, not only can several interesting contrasts and distinctions be drawn, but conclusions as to the future can be made. For this purpose the aeroplanes are compared according to the following essential features:

I. Mounting
II. Rudders
III. Keels
IV. Position of seats, motor, etc.
V. Position of center of gravity
VI. Transverse Control
VII. Aspect Ratio
VIII. Incident Angle
IX. Propellers
X. Structure and size
XI. Efficiency
XII. Speed and Flight

I. MOUNTING

There are three distinct types of mounting:

(a) Skids alone
(b) Wheels alone
(c) Skids and wheels combined

The necessity of providing springs on a heavy machine mounted on wheels has frequently been emphasized. M. Blériot has called attention to the fact that a high speed screw generates a small gyroscopic force which tends to resist all vibration or sudden changes of its axis. If, therefore, when running over the ground the machine be suddenly jarred, the propeller is likely to snap off.

This has often been experienced by M. Blériot himself, and was only obviated by the use of a very springy mounting.

The relative merits and demerits of mounting on wheels or skids are subjects of wide discussion. The advantages of mounting such as in the old Wright machine became very great when starting was to be made from soft soil or rough land, since the rail upon which the machine was placed could be laid down in almost any

VIEW FROM AN AEROPLANE IN FLIGHT

Photograph taken from the Antoinette in mid-air showing sheds and another Antoinette below. The top of one wing appears in the left of the picture.

kind of country, whereas wheels require a certain area of reasonably smooth and hard ground, a condition not always met with. A machine fitted with skids can withstand rougher landings, and upon alighting stop within a few feet. Furthermore, by using a rail, and, in addition, as was often done with Wright machines, a starting impulse given by a falling weight, a less powerful motor is needed for starting.

Nevertheless, the skid mounting has a great disadvantage in that a machine fitted with them, when once landed away from its starting rail, cannot again take to flight. This has caused skids alone to be disfavored by many aviators. Several combinations of skids with wheels have been proposed and tried, and some of the recent Wright machines have had wheels fixed to the skids to enable a fresh start immediately after landing. These combina-

LOOKING OVER THE BOWS OF THE ANTOINETTE TO THE FIELDS AND SHEDS BELOW

tions, of which the mounting on the Farman and the Sommer are typical, work with great satisfaction and appear at present to be most desirable for a heavy machine.

The conditions of landing and starting, of course, govern and are governed by the type of mounting used. In landing on rough ground with a Farman type chassis the wheels are likely to catch in brushes, etc., and cause considerable damage. Short Bros., well-known English aeroplane builders, have introduced a chassis on which the wheels used for starting are made to disappear and landing occurs directly on the skids.

The many different types of rubber rope, steel, and pneumatic springs, are all about equally serviceable. The rubber rope spring introduced by Blériot, is inexpensive, quite durable and very light.

Many of the recent Wright biplanes have not only had the axle of the wheels fitted with a very elastic rubber attachment, but have been equipped with an ingenious device, which enables the aviator to release the axle and cause the machine to rest heavily on the skids, while at the same time small hubs dig into the ground and prevent any motion. Hoxsey, on one occasion, at Belmont Park greatly amused the huge throng watching him return from an attempt at an altitude record, by descending to the ground, near the judge's stand, throttling down his motor, anchoring the machine by the device described above, and walking off to deliver his barograph sheet, while his propellers were turning at quite an appreciable speed. He then returned into the machine, released the "anchor," accelerated the motor, and took to flight.

Whatever the character of the mounting, it should be extremely strong. There is little doubt that had the Wright Gordon-Bennett racer, piloted by Brookins, been provided with a stronger mounting, the wreck that occurred would not have been so disastrous. As it was, this machine, carrying an enormously heavy loading, was suddenly deprived of the major part of its motive power, and lost headway. To the author, who was closely observing him as he was passing, barely a hundred feet away, Brookins appeared to be gliding to the ground, with skill and perfect control. As soon as he hit the ground, however, the wheels and skids crumpled like paper, and the machine was almost totally wrecked.

On aeroplanes such as the Curtiss and the Grade, where the loading is light, springy mountings have been found unnecessary.

It is likely, however, that the high speed aeroplane of the future will not only be provided with a very solid, elastic mounting, but will be projected from some ingenious starting device at high velocity so that it may be quickly launched into the air.

II. RUDDERS

The direction rudder in most of the main types is placed at the rear. The 1909 Cody biplane had an additional direction rudder in front, and the Voisin (Front Control 1911) has this disposition. All the monoplanes excepting the new Curtiss, Valkyrie, Blériot "Aero-bus" and Pfitzner have their elevation rudders at the rear, while in all biplanes, excepting the Breguet, Dufaux, Goupy,

A ROAD AS VIEWED FROM AN ANTOINETTE IN FLIGHT

and the 1911 Wright and Voisin types this rudder is placed out in front. Rudders placed at the rear are advantageous in that they act at the same time as keels. But in general the placing of the elevation rudder in front appears to offer more exact control of the longitudinal equilibrium.

The elevation rudder almost always exerts some supporting power. Therefore, when placed in front and turned up for ascent, the support is increased as it naturally should be. But when this rudder is placed at the rear the movement for ascent is such that the supporting power of the rudder is decreased and usually of negative value, so that instead of causing the front of the machine to rise, it merely causes the rear to sink. The same line of argument shows us that when starting, if the elevation rudder is out in front, the front of the machine lifts off the ground strongly and is followed by the body, while if this rudder be in the rear, when turned to give ascent, the rear merely sinks more, and not only is the length of run enormously increased, but the power absorbed and the danger incurred are greater. This is obviously a bad provision. That it is so generally used on monoplanes seems to be caused largely by the placing of the propeller at the front.

On the other hand, when, as on the (1909) Wright, the elevator is placed forward, it is exposed to the elements, and its great sensitiveness is bad in windy weather. When the elevator is placed behind, as on the monoplanes, it works in the slip stream of the propeller, a region that is turbulent, to be sure, but one in which the air motion is steady and constant in direction. It appears in addition that moving the elevator from the front to the rear of a biplane appreciably increases the speed. Farman designed a biplane without the front elevator many months ago, but has given it up. It is of interest to note, however, that the most recent type of Voisin biplane has both the elevation and direction rudders placed up front.

In some of the Wright biplanes the elevation rudder is so constructed that when elevated it is automatically warped concavely on the under side, and when depressed curved in the opposite way. This materially adds to the rudder's force due to the peculiar law of aerodynamics whereby a curved surface, under the same conditions as a flat surface, has a greater ratio of lift to drift. The reduction in size of the rudder that is thus afforded, and its flat shape, when normal, greatly reduce the head resistance.

In so far as the action of a biplane is usually supposed to cause interference of the two surfaces, and greater head resistance, it would appear as if the biplane rudders as used on the 1909 Wright and the 1909 Curtiss were not as efficient as single planes. But the structural advantage of this arrangement is great. It is important to note that on the latest Curtiss and Wright machines the elevator is a single plane.

The method used by Grade of only bending flexible surfaces, instead of turning fixed ones, has a great advantage in that the rudders after being used spring back to their normal position. This method has been adopted on several other types, and it has many considerations of safety favoring it.

A VIEW IN FRONT, FROM AN ANTOINETTE

The shadow effect is due to the propeller, which is whirling at high speed. The dark band is one of the blades. In the middle distance is a biplane in flight, and in the far distance a patch of woods.

In almost all the aeroplanes that are flying successfully, excepting, possibly, the Wright and the Antoinette, the size of the rudders is generally conceded to be much too great. This is clearly upheld by the usual remarkably small change of inclination of the rudder that is necessary for a change of direction. This ultra sensitiveness where, as in some machines, a movement of a few hundredths of an inch will considerably alter the state of equilibrium of the machine, is certainly undesirable. To begin with, it need hardly be pointed out that over-sensitiveness of a rudder invites dangerous situations. And, furthermore, if a rudder is extremely sensitive, then it is most likely too big, and if it is too big, then it is ab-

THE FARMAN MONOPLANE EXPERIMENTED WITH IN THE SPRING OF 1910

The Gnome motor and propeller are seen revolving rapidly at the front. The main plane is similar in construction to the Farman biplane surfaces. Ailerons are used for transverse control, and the rudders are at the rear. This machine was found very difficult to control. Note the tense position of the aviator seated back of the main plane.

sorbing power that could be put to better use elsewhere. We may therefore look to a great decrease in the size of rudders as a development of the near future.

For "volplaning," however, as pointed out in Chapter VII., Part I., larger rudders would give added safety.

III. KEELS

Keels on aeroplanes, like keels on a boat, aid in the stability. But on an aeroplane they are "dead surfaces," and as such have the disadvantage of offering greater expanse of surface for wind disturbance to act upon. Furthermore, they unquestionably deaden the motion and decrease the speed. Tapering keels such as used on the Antoinette, Pelterie, Nieuport, Etrich and the latest Blériot XIV., offer a maximum of "entering edge" with a minimum of area, and are for that reason more advantageous than rectangular shaped ones.

Separate keels are entirely absent in the Wright and Santos Dumont. The tapering bodies on the Breguet and many of the monoplanes are a distinct advance.

In the old Voisin type use was made of several vertical keels, partitions, placed not only at the rear, but also between the main surfaces themselves.

Keels add to the resistance of a machine the skin friction and consequent power absorption of such surfaces being considerable, and it is generally conceded now, that control by rudders is becoming so perfected that any inherent stability to be attained by use of keels at the expense of power is hardly worth the while. No special form or combination of keels that have so far been designed and tried have really succeeded in giving any kind of complete inherent stability.

Keels at the rear of a machine somewhat on the order of a bird's tail are nevertheless found advantageous, and we can expect to see such surfaces on aeroplanes for many years to come.

Actual practice shows that they do increase stability and tend to hold the machine to its course.

The reason for this is that they act like the tail of an arrow. If the rear has a high resistance and directive surfaces, and the front is heavily weighted, like the head of an arrow, then the stability is much more perfect. The Antoinette is designed in this way, and in its dart-like flight certainly gives an impression of unusual steadiness.

Many of the present types are equipped with lifting tails. In the Farman, as in many others, the propeller blast causes the tail to lift. This is considered by many to be a bad provision, because if the propeller suddenly stops, the tail at once sinks, and this causes the dangerous condition of loss of headway.

IV. POSITION OF SEATS, MOTOR, ETC.

The position of the seat and the motor is an important point in aeroplane construction. On monoplanes, generally, the seat is

FRONT VIEW OF THE FARMAN MONOPLANE

placed in the *fuselage*, between the main planes and well to the rear. In the Antoinette and the Breguet, the seat is placed in the frame at a point that is deemed the safest, *i.e.*, almost everything else will break before the aviator is touched. On the Wright, Curtiss, Farman, etc., the aviator sits at the front of the main cell. He commands here an uninterrupted view of the air about him, and the land below him.

In the old Antoinette and many of the Blériots provision for seeing clearly below was not made. This was very detrimental, and the collision that occurred at Milan, when Thomas on an Antoinette, crashed into Dickson's Farman below him, merely because he could not see him, made this defect so patently evident, that the wings of the new Antoinette at once were notched at the rear, so that the aviator could obtain a view of the region below him.

The position of the seat on the Pischof, Blériot XII., and Dorner is advantageous in that the aviator has a clear view below and on every side, can also watch the motor in front of him, and yet is comfortably placed, inside the frame, at a point that is in front of the propeller and fairly safe.

The Curtiss Monoplane Built Especially for the Gordon Bennett Race

It was not very successfully flown. The single plane elevator at the front and the side ailerons for transverse control are clearly seen. Note the similarity to the Curtiss biplane in the chassis construction. The aviator sits in front of the radiator.

The position of the motor at the back of the aviator as on the Curtiss is now generally considered an undesirable one. In case of a sudden plunge to the ground, and a consequent breakage, the motor would fall out of the frame and very likely pin the aviator under it.

Similarly its position above the aviator as on the Grade, Blériot "Aero-bus," and Santos-Dumont is dangerous, in that it would very likely crash through the frame and fall on the aviator's head, if the machine were suddenly to lose headway and sink to the ground.

In many cases aviators strap themselves into their seats, and the recent tragic death of Moisant, who was pitched head-long out of his seat when the machine suddenly dove down, bears out the wisdom of this measure.

The Maurice Farman and the Voisin were among the first prominent biplanes to have the seats and *fuselage* enclosed, and it is now recognized as quite necessary, especially for long duration flights, to protect the aviators from the head wind. The enclosed *fuselage* of the Paulhan and the new Farman "type Michelin," are as luxurious and as comfortable as "torpedo" body automobiles.

When the propeller is placed at the front there is still more reason for protecting the aviator as the air stream from the propeller is very disagreeable and likely to carry with it fine particles of oil, etc. McArdle in his flight of July 19th, 1910, on a Blériot, because of the film of oil that had formed over his eyes, thought he was in a heavy mist, lost his way, and failed to find the Beaulieu grounds, whither he was bound.

In fact, the provision of a proper degree of comfort for the aviator and his passengers is becoming so important that within a few years we may actually see in use completely inclosed bodies, resembling the cabins on motor boats. Certainly such a provision would enable aviators to guide their aeroplanes to much higher altitudes. A light canvas, aluminum, and mica-glass body shaped in stream line form is looked forward to as a very practical innovation.

V. POSITION OF CENTER OF GRAVITY

The most advantageous position of the center of gravity is being actively discussed at present, and it appears that no really definite conclusions can be reached. It is recognized in long flights, that the gradual diminution of the gasolene supply affects the equilibrium of the machine, unless the gasolene tank is placed over the center of pressure. On some of the "long-distance" Blériot XI. machines it is deemed necessary to put the gasolene tank low in the frame, in order not to bring the center of gravity too high; this position of the tank requires a pressure feed system. The idea in the new disposition of surfaces on the Farman "Michelin" seems to have been to raise the center of pressure so as to be able to carry an increased quantity of fuel in the usual position on the top of the lower plane, without any pressure feed to the engine.

The frequent *pique nez* of the Santos Dumont monoplanes, when, on landing, they stand right up on their nose, seems altogether to be due to a position of the center of gravity that is much too high. This, of course, is due to the placing of the motor above the plane.

A low center of gravity, as on the Pischof, is said by some to

THE "BADDECK No. 2" OF MESSRS. McCURDY AND BALDWIN

add greatly to the natural stability because of the pendulum effect, and by others it is thought to be detrimental to turning manœuvres and transverse stability. Actual observation of machines with a low center of gravity in flight shows that they are far more difficult to incline transversely than a machine with the center of gravity about in line with the propeller axis. Machines with the latter provision are easier to handle in almost every way.

The Antoinette is wonderfully well balanced, and the concentration of the weight of the motor at the front, and of the operator in the rear of the main surfaces gives perfect results.

It is doubtless a good provision to have the propeller axis a little above the center of resistance, as on the Wright, because the machine then tends continuously to dive downward, and therefore loss of headway with its serious consequences is not so likely to happen.

VI. TRANSVERSE CONTROL

In practice the lateral stability of aeroplanes is mainly preserved in five ways:

A. Automatically.

B. By warping of the main planes.

C. By balancing planes ("wing tips," or "ailerons").

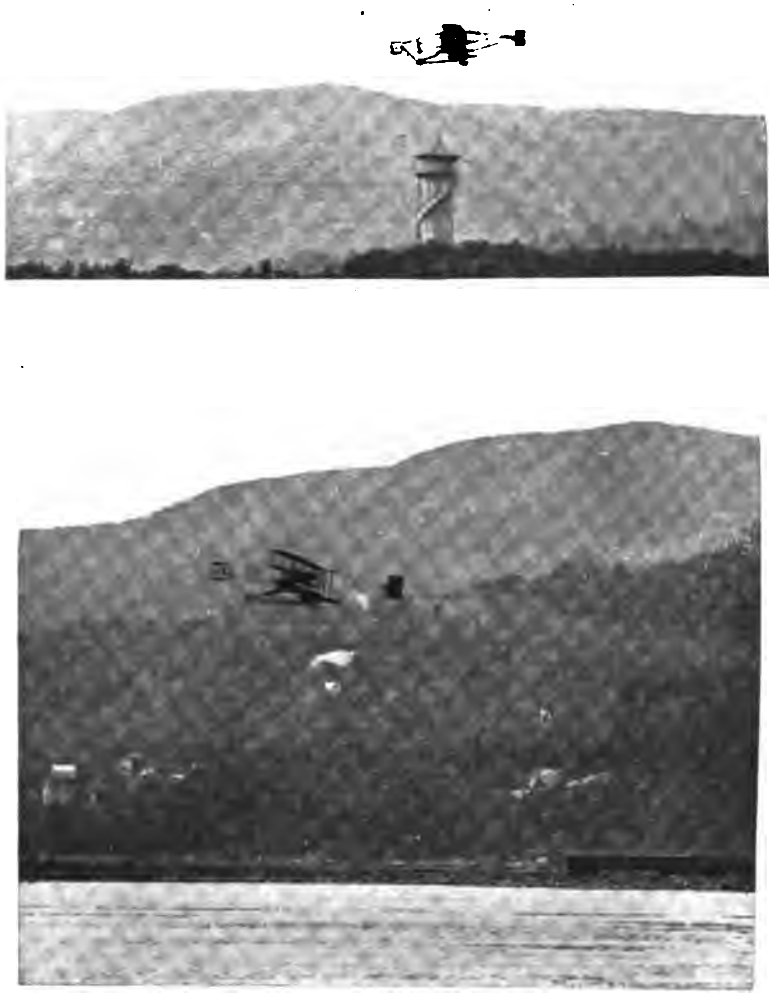
D. By sliding panels ("equalizers").

E. By vertical surfaces ("screens").

The old Voisin is the only type for which automatic lateral stability is claimed. The rear box cell and the vertical keels between the surfaces exert such a forcible "hold" on the air that to displace the machine is difficult and in all ordinary turmoils of the air it displays exceptional stability. A well-known aviator amusingly stated at Rheims in 1909 that were a Voisin tipped completely over on one end it would still be aero-dynamically supported, so great is the expanse of vertical surface.

Without such keels, however, the lateral balance of any aeroplane is so precarious that some form of control is necessary. The machines using the methods of warping the main planes for the preservation of lateral balance include in addition to the Wright, Breguet and Paulhan, all the present successful monoplane types except the Pfitzner, Valkyrie, and Blériot "Aero-bus."

Because of the structural difficulty of rigidly bracing the surface of a monoplane, warping is an ideal form of control. But the rigid structure of the biplane permits auxiliary planes (wing tips) to be more easily provided. This is done in the Farman, Cody, Dufaux, Neale, Goupy, Curtiss, Sommer, and the recent Voisin.



TWO VIEWS OF CURTISS ON HIS ALBANY TO NEW YORK FLIGHT

These two methods of transverse control are both very efficacious, but the additional resistance, unaccompanied by any increase of lift, which is produced by balancing planes, perhaps renders them less desirable than warping. On the other hand, there are objections to weakening the structure of the main surface by making it movable. Wing flexing weakens the spars by constant bending.

Ailerons on the trailing edge if inclined too much are likely to act only as brakes, while ailerons placed between the planes are found to be very inefficient.

There is a further distinction between these two methods of control which, although not thoroughly understood, appears to be borne out in practice, viz., when a plane is warped the action tends not only to tip the machine up on one side, but also due to the helical form assumed, there is a tendency to turn, which can only be counteracted by a vertical rudder. In the case of "wing tips," however, due to the equal but contrary position in which they are placed, both sides of the machine are equally retarded, and in addition, since the main surfaces preserve the same shape and the same angle of incidence, this tendency to turn appears to be absent. Mr. Curtiss states that for correction of tipping alone he makes no use whatever of the vertical rudder, while the Wright's claim that it is always necessary for them to turn the rudder to the side of least incidence.

Siding panels as applied to the Pfitzner monoplane and "screens" as used on the Neale biplane, represent two of the recently designed methods of transverse control which are thought to be no infringement on the patent rights of the Wright brothers. These systems have not been adequately tried out as yet, but there is no reason why they should not be as effective as the system of warping or the use of ailerons.

There are some other methods designed to give transverse control, and it seems at present that they are all equally reliable. Structural individualities of the types of aeroplanes will in all likelihood persist and we cannot picture the machine of the future with any one kind of transverse controlling apparatus. Wing tips, ailerons, are widely used at present, but further progress in aerodynamics is likely to show us that warping is better.

VII. ASPECT RATIO

It is at once observable from the values given in the tables on page 265 that the ratio of spread to depth (aspect ratio) of the monoplanes is generally less than that of the biplanes. This interesting fact is due very likely to the structural difficulty of making the wing of a monoplane long and narrow, and at the same time retaining the necessary strength without undue weight. The Antoinette builders have lately decreased the depth and

THE OLD "ANTOINETTE IV," PILOTED BY LATHAM OVER THE ENGLISH CHANNEL ON HIS FIRST UNSUCCESSFUL ATTEMPT TO CROSS

The transverse control was by means of ailerons on this machine.

increased the spread of this type of monoplane, thus increasing its aspect ratio, but the framework had to be greatly strengthened.

The Paulhan biplane has the highest aspect ratio of the present types, and exhibits remarkably good qualities.

Theoretically and experimentally the value of this quantity is known to have much to do with the ratio of lift to drift; but whether or not in actual practice, those machines like the Santos Dumont and Goupy having as low an aspect ratio as 3 to 1 are really inferior in their qualities of dynamic support to a machine like the Paulhan with as high an aspect ratio as 8 to 1, is difficult to determine, since many other quantities such as the loading and the velocity are involved. It is interesting to note here that some of the large soaring birds, notably the albatross, may be considered aeroplanes of very high aspect ratio.

The effect of aspect ratio upon speed is not discernible on comparing the types.

Greater stability, however, is commonly supposed to be given by a high aspect ratio, because of the decreased proportionate movement of the center of pressure.

The advantage and effects of aspect ratio are fully discussed in Chapter VII, Part I. It may be indicated here, however, that another advantage of aspect ratio is that for the same area the decreased movement of the center of pressure causes a smaller maximum moment tending to upset the aeroplane (see p. 82), and therefore permits of smaller rudders being used. It is valuable also to note that experiments in aerodynamics show the drift of planes with different aspects to be about the same, and that the lift alone increases greatly with the aspect ratio.

There is little question that a development in aeroplane construction in the near future will be an increase of the aspect ratio to even as high, possibly, as 12 to 1.

VIII. INCIDENT ANGLE

The incident angle (i. e., the angle, the main inclined surface makes with the horizontal line of flight) varies greatly in the different types. The Wright biplane is noticeable for its low angle of incidence in flight, which rarely exceeds two degrees.

Renard, after deductions from the experiments of Borda, as well as Langley and other investigators, have enunciated the principle that as the incident angle diminishes, the driving power expended in sustaining a given plane in the air also diminishes. Wil-

ASPECT RATIO TABLE OF MONOPLANES.

R. E. P. (1911)	6.5	Blériot XI. (Course)	4.5
Sommer	6.2	" (Cross channel)	4.35
Antoinette	6.	Nieuport	4.23
R. E. P. (1909)	5.75	Hanriot (1 seat)	4.2
Pfitzner	5.17	Tellier	4.2
Valkyrie	5.	Blériot XII.	4.
Etrich	4.72	Pischof	4.
Blériot XI. 2 *bis.*	4.7	Grade	3.9
Dorner	4.6	Santos Dumont	3.

ASPECT RATIO TABLE OF BIPLANES.

Paulhan	8.1	Wright (Model B.)	6.3
Breguet (40 to 50 H. P.)	7.9	" (G. B. Racer)	6.3
Dunne	7.6	" (1909)	6.25
Voisin (tractor)	7.4	Voisin (1909)	5.75
Wright (Model R)	7.4	Curtiss	5.65
Breguet (Course, 60 H.P.)	7.1	Dufaux	5.6
Cody (1911)	7.1	Voisin (Bordeaux)	5.6
Cody (1909)	7.	Neale	5.2
Farman ("Michelin")	6.8	Farman (1909)	5.
Curtiss (Passenger)	6.4	M. Farman	4.8
Sommer	6.35	Farman (Course)	4.2
		Goupy	3.

bur Wright states that "the angle of incidence is fixed by the area, weight, and speed alone. It varies directly as the weight, and inversely as the area and speed, although not in exact ratio." Faraud concludes that small angles are the most efficient for all aeroplanes. There is for each aeroplane a most efficient angle of incidence where

Duray at Nice, April, 1910

A remarkably clear photograph of a Farman biplane.

the power expended for flight is least. In flight the incidence should be kept constant at this value in order to obtain the highest speed.

The Farman, Voisin, Blériot, Grade, and Sommer have an angle of incidence when first starting much greater than when in flight. Since this involves greater drift resistance and consequently more power necessary to attain the velocity of levitation, and, furthermore, in view of the fact that aeroplanes with as heavy a loading but no excessive angle are able to rise after a reasonably short run, it would appear as if this provision were unnecessary.

There exist wide variations in this angle as observed and recorded for the different types, many of the present machines preserve their equilibrium during comparatively large changes of their longitudinal inclination.

In general the incident angle of the monoplanes is greater than that of the biplanes. The most common angle is in the neighborhood of 5 to 7 degrees. But in the Blériot "Aero-bus," an incident angle of 12 or 13 degrees is often used in flight.

Incidence will very likely be established purely by the lift-drift ratio of a plane, and the incidence kept as constant as possible to give this its highest value.

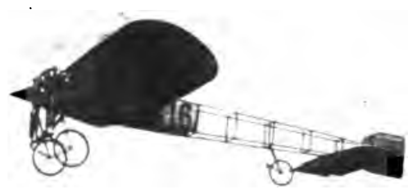
IX. PROPELLERS

Most of the aeroplanes are equipped with a single small high-speed screw.

The Wright and the Cody are the only machines provided with two propellers rotating in opposite directions. The greater efficiency of a propeller of large diameter and slow revolution over one of small diameter and high rotative speed has attracted much attention. This seems to be borne out especially in the case of the Wright machine, in which more thrust is obtained per unit of power than in any other type. The limit of rotative speed in practice is in the neighborhood of 1,500 r.p.m., and in most types the r.p.m. exceeds 1,000. Many of the aeroplanes use Chauviere wooden screws, for which an efficiency of 80 per cent is claimed. Metal propellers are not used much now.

The thrust and efficiency of the various propellers are about the same for equal sizes, and although the theory involved in the propeller is very little understood, the experimental methods used have enabled the design of propellers of as good or better efficiency than those used in marine practice.

The position of the propellers at the front in most of the monoplanes is largely a matter of convenience of design. The swiftly



DELAGRANGE ON HIS MONOPLANE (1909)

This was one of the first Blériot machines to be equipped with a Gnome rotary motor, and Delagrange's death was probably due to the fact that the frame was not strong enough to withstand the greater forces due to the higher power and speed.

moving mass of air from the propeller, however, exerts an added lift when thrown back on the plane. At the same time this action increases the resistance; but as the frame resistance of the monoplane is much less than that of the biplane, the propeller can be placed in front without very serious consequences. The Voisin (tractor type) was the first biplane to have the propeller at the front, and the results with the Breguet and Dufaux, indicate that this is in no way detrimental to the speed.

It is generally believed by aviators that much better results could be obtained by the use of propellers of 15 or 20 feet diameter rotating slowly. But there are two disadvantages involved in this feature of construction which makes its adoption in the machines of the future rather doubtful. The first is the greatly added weight of so big a propeller and the second the difficulty of building a good chassis high enough to permit of the propeller's rotating freely.

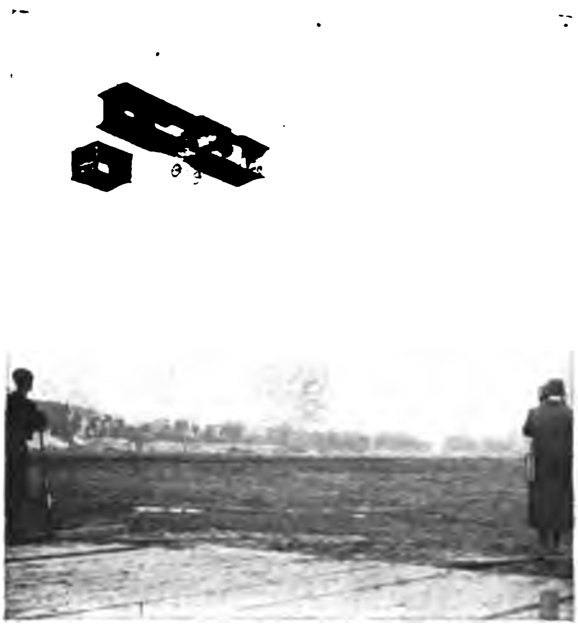
X. STRUCTURE AND SIZE

Most engineers are impressed with the fact that in general the structural features of present-day aeroplanes are "amateurish." This is no doubt well founded in many cases, and aeroplanes have been built and are now building of so flimsy a character that aviators should be forbidden by law to fly them. But when the details of a well-designed and constructed type like the Antoinette are examined, the excellence of the workmanship is at once apparent.

The general type of aeroplane structure is certainly capable of immense improvement and modification. The primary reason for the more or less backwardness in this respect, is that the greater part of the thought and time of constructors has been spent on motors. Now, however, motors are becoming rapidly a secondary consideration. Any number of good ones are on the market, and many of them work with perfect satisfaction for months.

The Fabre type of construction as used on the Paulhan (explained on p. 210) is a distinct step in advance, as is also the metal construction of Breguet. During the past year the use of steel tubing and stronger metal parts has become much more prevalent, and the era of the all-steel aeroplane with riveted or pin-connected joints, I-bar and T-bar struts and spars, and thin steel sheeting for the planes is not far distant. In monoplanes for example, a steel central frame, with two tension members bracing the planes to it below, and two compression members above, forming a rigid truss, would be slightly heavier to be sure, but still ever so much stronger than the steel ribbon and cross-wire structure now used, with tension members above the plane, in many cases inactive and useless when the machine is in flight.

The size of aeroplanes varies in the different types, but between limits that appear well marked. The "waist-pocket" aeroplane is a phantasy, and the one hundred passenger machine is still in the dim future, although it has possiblities of success. The compara-



PAULHAN ON HIS VOISIN, OCT., 1909

tive diagrams of the aeroplanes (see Part II) give an insight into their relative sizes, in far better fashion than words can do.

XI. EFFICIENCY.

One of the best indications of the general efficiency of an aeroplane is the amount of weight carried per unit of motive power. This quantity is usually termed the "pounds per horse-power," and is arrived at by dividing the total weight of the machine in flight by the horse-power of the motor. In the Tables on p. 274 and p. 275

the pounds per horse-power for each type are given numerically and in order of magnitude.

The Blériot XI. (racing model) appears at present to be the most wasteful of power, while the 1909 Wright was by far the most efficient. It must be borne in mind, however, that the Blériot is much faster than the Wright. The Grade, Sommer, Dufaux,

BLÉRIOT ON A CROSS-COUNTRY TRIP

The very flat nature of the country over which so many of the French aviators make extended flights is evident.

Wright (racer) and Santos Dumont, appear also to be inefficient in this regard.

The Dorner, Nieuport and Breguet rank high, as do also the Farman passenger machine, the Antoinette and the Voisin (Bordeaux).

There is no special variation of this quantity with size, however, and it can only be pointed out that those machines using a high angle of incidence appear to be the most wasteful of power. The Wright has the lowest incidence, and utilizes its power best. But the use of two propellers instead of one in the case of the Wright, has probably much to do with its power economy. Less pounds are lifted per horse-power by the faster machines, but their speed, in itself, is a factor of efficiency.

There is also no general distinction between the monoplanes and the biplanes as regards the weight per horse-power.

A more direct indication of the aerodynamic qualities of the aeroplanes is the lifting power of the planes. This quantity, termed the "pounds per square foot" or "loading," is arrived at by dividing the total weight by the area of the sustaining planes, and represents the number of pounds carried per square foot of the surface.

A machine carrying a very light loading, however, is not necessarily inefficient, since many quantities such as the velocity, the height it is desired to attain, and other questions of design, enter into the determination of this loading.

As regards speed, the loading can theoreticaly be taken as a direct indication of speed, because the heavier the loading, the greater is the speed necessary for support.

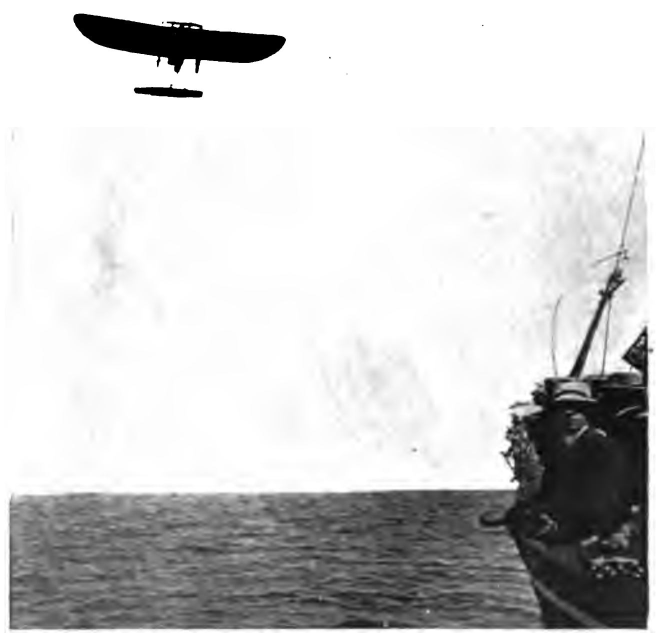
There are many surfaces, however, that appear to be more efficient than others, in that they can carry much more loading without decreasing to any great extent the ease with which the aeroplane can take to flight.

The effect of heavy loading on the landing of the aeroplane is naturally to make the landing shock very great. In the case of the Wright (racer), which had the heaviest loading, it was necessary in order to avoid this shock, to keep the propeller running at full speed even when alighting. This condition is undesirable and requires a large area to land in.

The machine with heavy loading when in actual flight, however, is less likely to be affected by slight pulsations of the air, since it tends more to cut through them because of its small buoyancy.

A heavily loaded machine cannot soar or glide as well as a lightly loaded one, nor can it rise to as great a height. This is a distinct disadvantage, especially in view of the recent high flying and what it augurs for the future in the way of soaring with motor cut off for long stretches of time and at great elevations.

Another bad effect of heavy loading on an aeroplane is the difficulty it has of starting in a wind; and the ease with which lightly



BLÉRIOT IN MID-CHANNEL

loaded aeroplanes take to flight in squally weather was especially noticed at the recent aviation meetings.

Heavy loading, however, involves also the question of economy, since less material need be used, and the design can be made more compact.

In the Tables on page 274, the loading for each type is given numerically.

The Grade and the Wright have the lightest loading, while the Blériot XI. (racer) and the Wright (racer) have the heaviest. It is particularly noticeable that in general the monoplanes are more heavily loaded than the biplanes, the Grade being an exception. This, however, is not accompanied by any generally remarkable high-speed qualities of the monoplanes, as would be expected, but is probably due to the interference in lifting of the surfaces of a biplane with each other.

TABLE OF POUNDS PER SQUARE FOOT OF SURFACE.

MONOPLANES

Blériot XI. (Course) ...	5.76	Sommer	3.8
" XII.	5.3	Pischof	3.65
R. E. P. (1911).......	4.6	Valkyrie	3.5
Blériot XI. (cross channel)	4.5	Antoinette	3.33
Nieuport	4.5	Etrich	3.2
R. E. P. (1909)	4.4	Pfitzner	3.2
Hanriot (1 seat)	4.15	Santos Dumont	3.1
Blériot XI., 2 *bis*	4.1	Dorner	3.
Tellier	4.	Grade	2.

TABLE OF POUNDS PER SQUARE FOOT OF SURFACE.

BIPLANES

Wright (G. B. Racer)....	5.92		
Breguet (Course 60 H.P.)	5.4	Cody (1910)	2.8
Breguet (40 to 50 H.P.)..	4.4	Sommer	2.76
Goupy	4.2	Cody (1911)	2.8
Wright (Roadster)	4.2	Curtiss	2.5
Curtiss (Passenger)	3.64	Neale	2.5
Farman (Michelin)	3.4	Wright (1911)	2.5
Paulhan	3.28	Voisin (1909)	2.37
Dunne	3.2	" (tractor)	2.36
Voisin (Bordeaux)	3.14	M. Farman	2.35
Farman (Course)	3.	Dufaux	2.1
" (1909)	2.8	Wright (1909)	2.05

TABLE OF POUNDS PER HORSE-POWER FOR MONOPLANES

Dorner	39.	Etrich	20.
Nieuport	35.	Tellier	19.
Antoinette	27.	Pischof	17.5
R. E. P. (1909)	27.	Grade	17.
Pfitzner	24.	Hanriot (1 seat)	15.2
R. E. P. (1911)	22.5	Blériot (XI. Cross Chan.)	14.4
Valkyrie	22.5	Sommer	14.
Blériot (XI. 2 *bis*)	21.	Santos Dumont	12.
" (XII.)	21.	Blériot XI. (Course)	7.5

TABLE OF POUNDS PER HORSE-POWER FOR BIPLANES

Wright (1909)	41.	Farman (1909)	24.
" (1911)	37.	Voisin (1909)	23.
Farman ("Michelin")	37.	Curtiss (Passenger)	22.6
Breguet (40 to 50 H.P.)	36.	Curtiss	22.
Dunne	34.	Farman (Course)	21.
Neale	28.5	M. Farman	21.
Voisin (Bordeaux)	28.	Goupy	21.
Wright (Roadster)	25.4	Paulhan	21.
Breguet (Course 60 H.P.)	25.	Voisin (tractor)	19.
Cody (1909)	25.	Sommer	16.
" (1911)	25.	Wright (G. B. Racer)	14.3
		Dufaux	11.

XII. SPEED AND FLIGHT

The speeds of these aeroplane types are given numerically in the Tables on page. 277. It can be seen at once that the speeds of the machines are all very much alike, the monoplanes not being in general any faster than the biplanes. The Blériot XI. (racer) and the Wright (racer) are now the fastest, and the Farman (Michelin) the slowest. It is noticeable that the speeds of aeroplanes as designed at present seem to have a well-defined limit beyond which it is difficult to pass. M. Blériot in 1909 made 36 miles an hour on a monoplane driven by a 25 horse-power engine. Upon subsequently increasing the power to 50 horse-power he was barely able to reach a speed of 54 miles a hour, and upon increasing the power to 100 horse-power this year, he was, with the same type, able to make only 58 miles an hour. He then altered the design and finally Leblanc and Morane were able to make over 68 miles an hour.

The speed shows no direct variation with aspect ratio or loading, and higher speed appears to be attained mainly by an excess of power, a decrease of head resistance, and a small size of plane.

It seems doubtful at present whether we can, in an aeroplane, ever get up to a speed of 100 miles an hour. It is quite certain that to accomplish this the general type of aeroplane we now have will need considerable alteration.

In the manner of flight of the different types pronounced distinctions can be drawn.

Probably the widest variation in manner of flight exists between the Antoinette and Farman.

The flight of the Farman machine can best be described as "sluggish." The enormous resistance of this machine seems almost visibly to hold it back, and in making turns the action is slow and "deadened."

In contrast to this is the strikingly birdlike flight of the Antoinette. The resistance of this aeroplane is very small, and consequently the machine darts easily through the air. When changing the direction in any sense or when correcting its stability, the action is precise and well-nigh instantaneous. There is little question that the Antoinette answers its helm better than any other type.

The Blériot approaches the Antoinette in maniability, and the gracefulness of its form makes it also appear very birdlike. The Grade because of its light loading seems especially buoyant on the air, and the other types have characteristics intermediate between the extreme sluggishness of the Farman and large Wright and the preciseness of the Antoinette.

TABLE OF SPEED OF MONOPLANES

Blériot XI. (Course)	69.	Etrich	51.
R. E. P. (1911)	60.	Hanriot	51.
Santos Dumont	55.	Dorner	50.
Sommer	54.	Blériot XI (Cross Chan.)	48.
Pischof	53.	" XII.	48.
Tellier	53.	Valkyrie	46.
Nieuport	52.5	Blériot XI. 2 *bis*	42.
Antoinette	52.	Pfitzner	42.
Grade	52.	R. E. P. (1909)	39.

TABLE OF SPEED OF BIPLANES

Wright (G. B. Racer)	67.5	Voisin (1909)	35.
Breguet (Course 60 H.P.)	62.	Sommer	46.
Wright (Roadster)	54.5	Goupy	45.
Breguet (40 to 50 H.P.)	53.	Farman (Course)	44.
Voisin (Bordeaux)	51.	Neale	42.
Dufaux	50.	Wright (1911)	42.
Paulhan	50.	Cody (1911)	41.
Voisin (tractor)	50.	Wright (1909)	40.
Curtiss	49.	Dunne	38.
M. Farman	47.	Cody (1909)	37.
Curtiss (Passenger)	46.	Farman (1909)	37.
		Farman (Michelin)	34.

Rougier Flying a Voisin Over the Sea at Monaco

CHAPTER XIII.

CONTROLLING APPARATUS

The system of control is so important a part of an aeroplane that it is well worth while before treating of accidents to consider the principal controlling systems that are in use more fully than is done in Part II. in order to bring out clearly the distinctions.

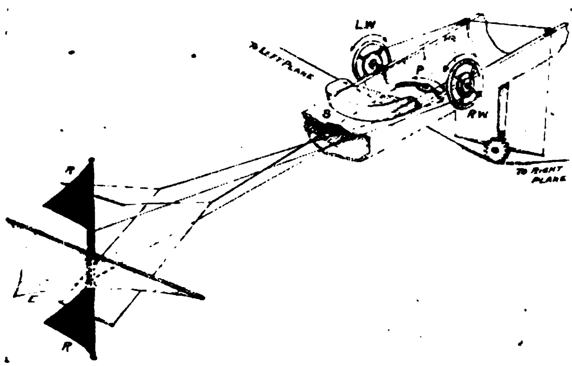
It must be borne in mind, however, that the system of control shown for any one type is not necessarily the one used on every machine of that make. Quite the contrary—there are wide variations from the standard system in every make, dependent primarily on the desire of the purchaser. For example, where foot pedals are used to control the direction rudder, there are two ways of connecting the control wires. The first is to connect them straight, without crossing each other; the control requires in this case that to turn, let us say, to the left, the foot bar be pushed on by the left foot. Many consider this an uninstinctive and therefore undesirable disposition and prefer to have the wires crossed, so that to turn to the left. the right foot is pushed out and the left foot pulled in. the motion being similar to that of an axle placed at the front or the handle-bar on a bicycle. In almost all the foot pedal controls here represented. the latter disposition is given, although in some types, notably the Blériot, the former disposition is more widely used. In many cases the full connections of the control system are not shown in order to avoid complications: these sketches are merely diagrammatic and distorted for explanatory purposes.

1. THE ANTOINETTE

In the diagram on p. 280 is shown the controlling system of the Antoinette. The aviator seated at S, has a wheel at his right hand RW. controlling the elevation rudder E. and one at his left hand LW. controlling the warping of the main planes. A foot pedal P, operates the direction rudders RR.

If the machine were suddenly to plunge downward, the aviator would quickly turn RW in a counter-clockwise direction and thus turn up E and right the machine. The transmission by crossed wires from the drum of the hand wheel to the arm of the rudder can readily be followed. Due to the variable pull of his propeller and the constant shifting of the center of pressure, Latham is almost continuously jockeying the elevation rudder, slightly, up and down, as one who has seen him in flight could clearly observe.

If the machine tips down suddenly on the left side, then the wire marked "to left plane" must be pulled in, in order that the



THE CONTROLLING SYSTEM OF THE ANTOINETTE MONOPLANE

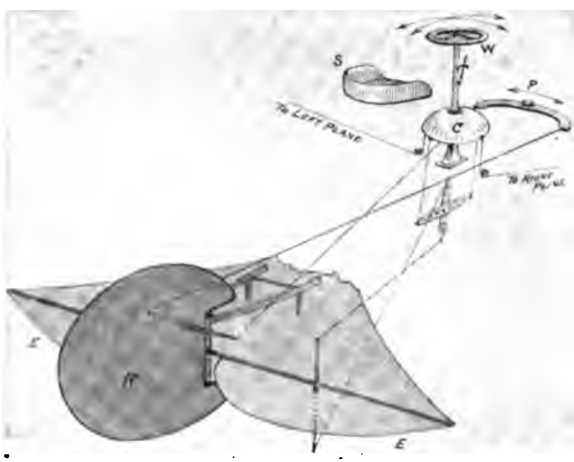
incidence of the left plane may be increased. To do this the cog mounted on the strut under the frame, and which carries with it the cross arm holding the wires, must be moved in a counter clockwise direction. Therefore the right end of the cross arm must be pulled up, and the left down. By following the wires over their respective pulleys it will be at once observed that to do this, the wheel LW must be turned counter-clockwise. Conversely, to tip up the machine on the right side, LW is moved clockwise, thus pulling in the wire marked "to right plane."

To turn to the left, the aviator pushes on the pedal P with his right foot and thus turns rudders RR exactly as on a boat. If the wires were not crossed, he would push on P with his left foot for a left turn.

The control system of the Antoinette is ingenious, but hardly instinctive. In fact this is one of the hardest machines to drive, with the possible exception of the Wright.

2. BLÉRIOT

The controlling system of the Blériot "militaire" is shown roughly in the diagram below. The mechanism for the warping wires consisting of a shaft and drum over which the wires lead down to pulleys on the frame strut below the fuselage, and thence out to the planes, is not shown. The wires from the foot pedal are here shown crossed, although the more usual practice appears to be to have them leading direct from the ends of the pedal to the rudder bar.



THE CONTROLLING SYSTEM OF THE BLÉRIOT MONOPLANE

The aviator seated at S operates the rudder R by the bar P as already explained for the Antoinette. In front of him, between his legs, is the *cloche*, consisting of the bell C, a post and the small wheel W. This wheel cannot be turned and is merely ornamental. The entire *cloche*, however, is universally pivoted and can be moved forward and back or side to side.

By means of the two wires marked "to left plane" and "to right plane," and attached on the side of the *cloche*, the aviator controls the transverse balance. If the left side suddenly tips down, then the *cloche* is quickly moved over to the right, thus pulling in on wire "to left plane," and increasing the incidence of the left side. This action actually, however, takes place through the shaft and drum (not shown).

The flaps of the elevation rudder EE, are controlled by the front to back motion of the *cloche* acting through the wires on the bell and the double lever arm below in such a way that to cause ascent the *cloche* is pulled back towards the seat S, and for descent it is pushed forward.

The Blériot control is instinctive and easy to acquire.

3. BREGUET

On p. 283 is a diagrammatic sketch of the Breguet controlling system, which is probably the most instinctive one in use. All the three controls are united at one place, and all can be operated separately or together as desired. The wire connections are shown very simply here, although on the machine itself the connections are much more complicated. The manner in which the axle of the front wheel is operated in combination with the rudder is likewise not shown.

The wheel W, resembling the wheel on a motor boat, is mounted on an axle at the top of a strong post. This post is mounted on two axes at right angles, thus enabling it to be moved side to side or forward and back.

The side-to-side motion of the post controls the warping through wires "to left plane" and "to right plane" precisely as on the Blériot, the inclination of the post away from any side causing that side to rise up.

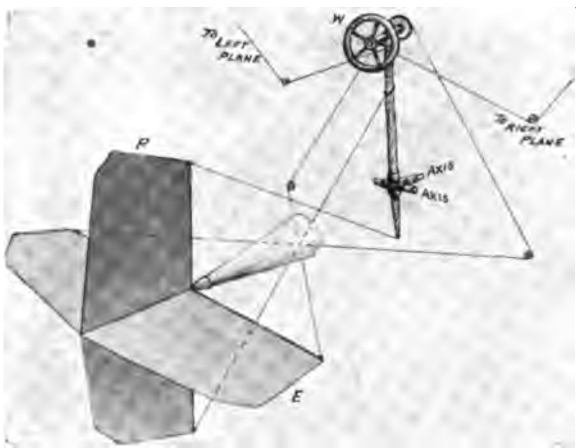
The rudders R and E are rigidly connected, and are together mounted on a single universal joint at the rear of the frame. Therefore whenever R moves from side to side, E swings around from side to side with it and vice versa.

To ascend the aviator pulls the post, wheel W and all towards him. This turns up the tail E and ascent follows.

To turn to any side the wheel W is turned exactly as on an automobile or motor boat. A combined action of warping and rudder for turning is also rendered possible by this system.

It is of importance to point out that in this type of control, the aviator has nothing to hold on to but wheel W, and can therefore, if expert, control the entire machine with one hand.

No simpler controlling apparatus has ever been used, and there



THE BREGUET CONTROLLING SYSTEM

is no doubt that this type has therein an immense advantage over all others.

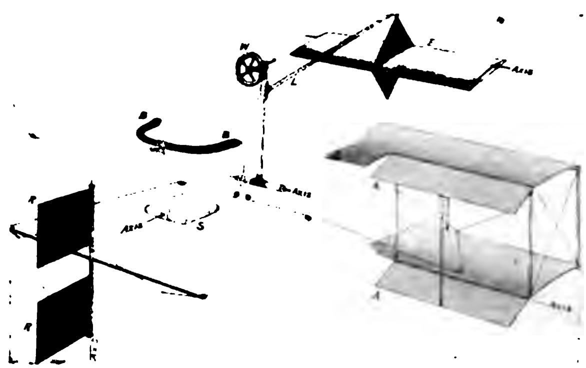
4. CURTISS

The outstanding feature of the Curtiss system shown in the diagram on page 284 is the operation of the side-control by a brace BB, fitting around the back and arms of the aviator and pivoted on the seat S.

AA are the ailerons of the right side mounted on the trailing edges of the planes with a small steel rod between them, as used on many of the recent Curtiss biplanes. Wires lead from them to the back of the brace as shown. If the machine suddenly tips down on the right side, it will be necessary to turn down AA, and thus lift up the side. This is done by a very natural movement —i. e., the aviator leans towards the left away from the lowered side.

In front of the seat S is pivoted a post capable of front to back motion, and upon which is mounted a wheel W.

The direction rudders RR are controlled by wheel W exactly as the rudder on a boat. To turn to the right wheel W is turned clockwise.



THE CURTISS CONTROLLING SYSTEM

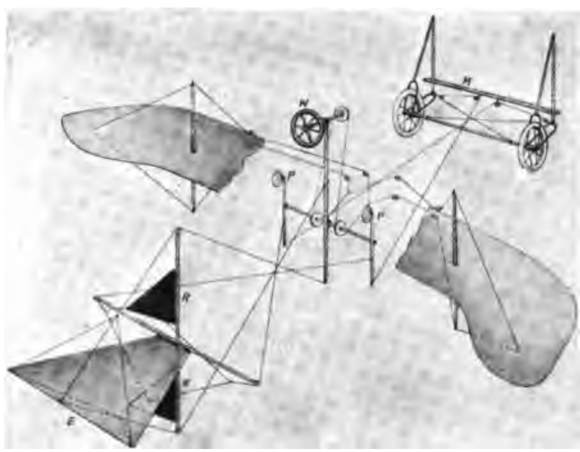
The control post is connected by a long strut L to the elevation rudder E as shown. On the recent Curtiss machines the elevation rudder is a single plane. By pulling the wheel and post towards him, the aviator will obviously turn up the elevator E and will therefore ascend. To descend the wheel and post are pushed forward thus turning down E.

5. ETRICH

The system of control of the Etrich monoplane shown in the diagram on p. 285 appears at first hand to be quite complicated, but it is really very instinctive and works well in practice.

A steering wheel W, governing the warping of the planes, is mounted on a post which can be moved forward and back to control the elevation rudder E. Two foot pedals PP control in unison the direction rudders RR and the wheels on the mounting chassis M.

If the machine suddenly tips down on the left then the wheel W is turned clockwise, thus increasing the incidence of the left side and turning up the rear of the wing on the right side. The turbine effect that is said to take place on this lowered side has already been explained on p. 123.



THE SYSTEM OF CONTROL OF RUDDERS, ETC., ON THE ETRICH MONOPLANE

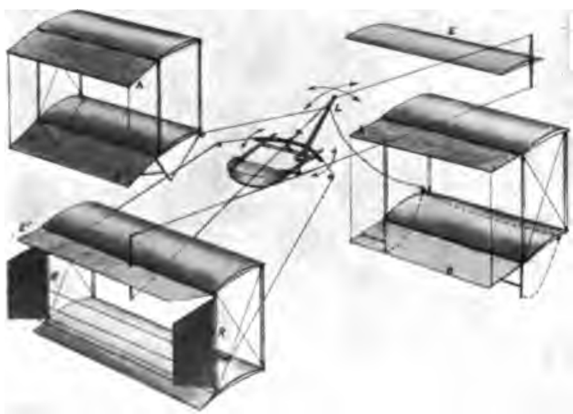
The forward and back motion of the post for control of the elevator E is exactly as on the Breguet.

To turn to any side the foot pedal on that side is pressed down. This not only turns the rudders but also the wheels on the chassis as on an automobile. The wire connections must be followed through in order to understand this movement. To turn to the left for example, the left pedal P is pressed down.

6. FARMAN

The Farman single lever and foot pedal control shown in the diagram on p. 286, is probably the most widely used at present. A large lever L mounted on a universal joint is moved forward and back for control of the elevators EE′, and side to side for control of the ailerons. A foot bar P controls the direction rudders RR in the usual manner.

The two parts of the elevation control consisting of the single plane E at the front and the rear flap E′ of the upper deck of the rear cell, are moved jointly by the lever L. Pushing lever L forward will cause E to be turned down and also E′ to be turned down, so that the machine will descend. To ascend the lever is pulled in.



THE FARMAN CONTROLLING SYSTEM

If the left side suddenly tipped down then the lever would be moved over to the right as shown. This movement acts by wires on the left ailerons, and pulls them down, thus increasing the lift on that side and causing the machine to rise on that end. At the same time, however, the wires leading to the ailerons on the right side are slacked and they merely flap freely in the wind stream.

This control is very simple and is about as easy to acquire as the Blériot.

For safety the wires leading from the lever to the ailerons and rudders are made double.

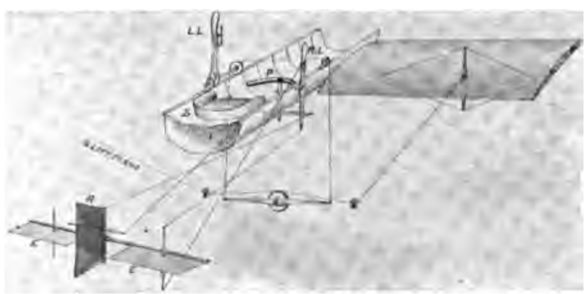
7. HANRIOT

The Hanriot control shown on this page resembles the Antoinette excepting that levers are used instead of wheels. A foot pedal P operating the rudder R is used in the usual fashion.

RL, a lever in the aviator's right hand, can be moved forward and back and controls the elevation rudders EE. When pushed forward, the rudders are turned down and the machine descends; when the lever is pulled back, the machine ascends.

The lever in the aviator's left hand LL is moved from side to side and with it moves the axle and drum to which the cross arm wires are attached, shown on the edge of the left upper side of the skiff-like body.

The wires lead from this drum down to a crossarm which is rigidly fixed to a second drum to which the actual warping wires



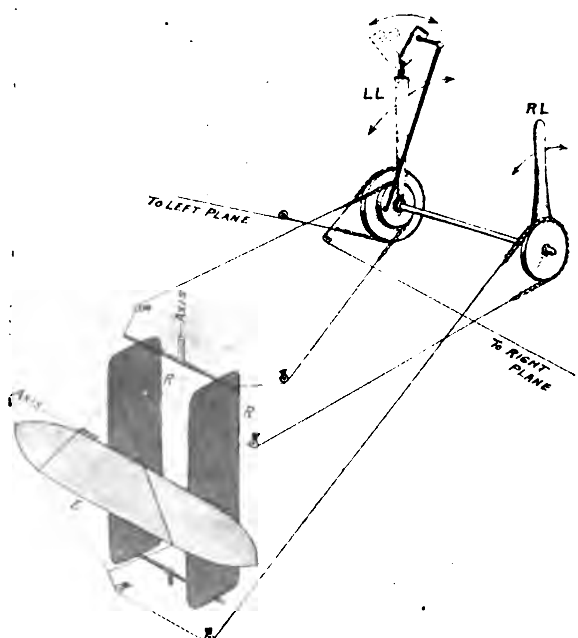
THE HANRIOT CONTROLLING SYSTEM

are attached. If the right side sinks, then to correct the equilibrium the lever LL is moved over to the left. This causes the lower drum and crossarm to move counter clockwise, and by pulling on the wire leading to the right wing, causes its incidence and therefore its lift to be increased.

8. WRIGHT

The new Wright controlling system, see p. 288, is at once the most complicated and the simplest of all the different systems used. The operation is simple enough. The structure, however, is quite intricate.

The system shown below is one of many Wright systems, there being several modifications, depending primarily on whether the operator elevates with his right hand as Wilbur Wright, or with his left hand as Orville Wright, and Brookins. In some instances all the wheels and chains are at one side, and the motion of the outside lever carried through by an inner tube or rod.



THE WRIGHT CONTROLLING SYSTEM

The operation of the elevation rudder E by the lever RL, consists merely in pushing the lever forward for descent, and pulling it in for ascent.

The lever marked LL operates the rudder and warping combined by a front and back motion. This lever has a movable handle which permits of its being "broken," i. e.: the handle moved side to side. To "break" a Wright warping and rudder lever is merely to operate this handle.

As already stated, a front to back motion of this lever causes both the warping and the rudders RR to be operated in unison.

THE MACHINE FOR THE INSTRUCTION OF AVIATORS AT THE ANTOINETTE SCHOOL

The instructor throws the seat in various directions and the pupil, by operating the controls, learns not only to correct any change of position, but is able, after much practice, to catch and prevent any disturbing movement.

But the chains and drums of these two motions although both mounted on the same shaft, are not connected. Therefore the smaller one governing the rudder RR can be moved independently of the other by "breaking" the lever.

If it was desired for example to perform a very sharp turn to the left the operation would be as follows. The machine is first inclined upward on the right by pushing out on lever LL. This pulls in wire "to right plane" and causes that side to be warped down and therefore to rise. Pushing out on lever LL also causes the rudder RR to be turned to the left (for a left turn). The machine has now acquired the requisite centrifugal action and the lever LL is brought back, but at the same time it is "broken" forcibly over to the left, thus turning the rudder RR alone and causing the machine to "skew" around almost on end. If a spiral "corkscrew" dip were to be executed the same process would be employed, except that in the beginning the elevator would be turned down for a dive to give momentum to the machine, and bring the rudder and warping action into play more strongly.

These are the principal controlling systems, and they differ in degrees of instinctiveness and grouping in which the various motions are united.

The main questions in any controlling system and the ones that can really be settled only by individual preference are:

(1) Whether the control should be direct or indirect, whether the motion of the control should be in the direction in which the machine is to react or opposite to it.

(2) Whether the different controls are to be united at one place, as on the Breguet, or divided separately, as on the Antoinette.

No general advantages of any one system over any other can be laid down because, of course, what appears instinctive to one man, may appear very difficult to another.

CHAPTER XIV.

ACCIDENTS

"La prudence est la vertu des aviateurs."
L. Paulhan.

Railroads, automobiles and in fact all forms of locomotion have their victims. Great mine disasters, industrial catastrophies, fires and explosions claim their toll of human life. But so small does the proportion of fatalities appear to be, that we do not for a moment consider any of these means of locomotion or lines of human endeavor as really dangerous.

Yet the many recent tragedies in aviation are so graphically portrayed and so absorbingly dwelt upon by the press and the public in general that the realization of the negligence on the part of the very aviators who are killed is often obscured. The hasty judgment of the all too credulous world is passed, that it is the aeroplane itself that is fundamentally dangerous.

As a matter of fact, however, if the great care and judgment that is necessary be properly exercised, aviation is as safe if not safer than automobiling. But in the ability to execute this care and judgment lies the striking difference between Wilbur Wright, Curtiss, Blériot, Farman and the other aviators of the "old school" to whom accidents rarely if ever happen, and the increasing group of reckless and untutored "daredevils," who perform their highly dangerous spirals and volplanes in almost impossible weather, and who in the end usually suffer the tragic death that is awaiting them.

It is as absurd for an aeroplane to be taken out and flown under weather conditions peculiarly hazardous to it alone, as it is for a sailing boat to set out full sail into the teeth of a hurricane.

Almost every summer in the vicinity of New York there occur high and unexpected windstorms, and the next day the newspapers invariably report the loss in human life in drowning from over-turned sailing craft as anywhere between 10 and 30 victims. It is not every day, by any means, that sailing boats can be navigated in safety and the prudent mariner recognizes this and risks neither himself nor his craft. It is infinitely more important to consider

A LIFE PRESERVING GARMENT FOR AVIATORS, WHICH FORMS INTO A PARACHUTE ON FALLING.

the conditions of the atmosphere in aviation. And yet, by the novices they are almost ignored. Flying is indulged in, generally, both here and abroad, in wind conditions that are prohibitive to safety and in almost every case accidents can be traced directly to this source.

Laffont and Pola, Hoxsey and Moisant are but a few of the victims of their own folly in daring to venture as they did into the swirls and turmoils of the upper air, the existence of which experienced aviators warned them of.

All these catastrophes have a cause, but that which stupefies everyone is that in many cases the cause remains unknown. The fatal plunge is often laid to a broken wire, a splintered spar and finally to a collapsed wing; but a moment of thoughtful investigation shows that all these are not the causes at all. They are merely the effects. Some peculiar combination of forces and pressures has overstrained the part and caused its breakage. In many

A WRECK OF A BLÉRIOT

On Sunday, Oct. 23rd, 1910, at Belmont Park, Moisant attempted to fly his Blériot XI 2 bis in a gale. The machine capsized with the result here depicted.

cases the fall takes place without any breakage at all and can only be due to a loss of equilibrium caused by the disturbing forces.

Whatever the cause, one fact stands out with enormous significance:

Over 80 per cent. of the accidents that have taken place have occurred in conditions of wind that were easily recognized as dangerous.

There have been such conflicting reports about many of the accidents that it is almost impossible to describe and explain them.

There are at present, however, nine distinct ways in which accidents are observed to take place.

1. The aviator appears to lose control; the aeroplane begins to sway and dive uncertainly, and finally it lands heavily and is smashed with more or less fatal results to its driver. This has been observed in all kinds of weather, both calm and windy.

2. The aeroplane collides with obstructions either when landing, starting or in mid-air.

3. The aeroplane appears to land too heavily and is in consequence more or less totally wrecked.

THE WRECK OF A FARMAN BIPLANE

At Nice, April 17th, 1910, Chavez on his Farman was suddenly deprived of fuel. The biplane lost headway and landed heavily on the beach, the chassis being completely smashed.

4. In making a turn the equilibrium appears to be lost, and the machine falls in various ways. This is seen to happen most frequently to novices, especially on Blériot-Gnomes.

5. The aeroplane, due to sudden stoppage of the motor, loses headway and falls tail on to the ground.

6. The aeroplane appears to break apart in some way in mid-air while in full horizontal flight, or a broken spar or wire causes loss of balance.

7. While in ordinary motor flight the aeroplane is seen to pitch forward suddenly and dive head on down to the ground, appearing to have lost its support, although no breakage is observed.

8. A similar sudden plunge is frequently seen to occur when the aeroplane is in *volplané*.

9. At the instant when, after a long downward dip, the aeroplane is turned up in order to land tangentially, the wings appear to break loose and fold up overhead with a terrific force.

THE DAMAGE DONE TO AN ANTOINETTE BY A HEAVY "HEAD-ON" LANDING

The propeller and one wheel are damaged. The planes and frame are intact.

Accidents that occur in the first six ways are easily explainable, and as easily avoidable by the exercise of skill and care. Accidents represented by ways 7, 8 and 9, however, are extremely hard to explain and are causing aviators, constructors, and experts alike a great deal of worry. It is an especial object of this chapter. to present two very plausible explanations of these kinds of accidents, that, if recognized as true, will lead to their practical elimination.

I.

That it is possible for aviators themselves to become physically unable to control their machines, especially after a rapid descent from a high altitude is now believed to be a fact. Labouchére has described at great length the feeling of extreme nausea that came over him when about to return from a high flight. Morane says that on one occasion after turning off the motor and starting to swoop down from a high altitude, he became so dizzy and felt so ill that he lost completely the control of the machine, and was saved only by fortunate circumstances. Drexel and Latham also testify to this effect of altitude and consider it a form of "mountain

A Wrecked Antoinette at Heliopolis, Egypt, in 1910

sickness." It is said that Chavez, at the end of his great trans-Alpine trip, was affected by this dizziness, and that his fall was due primarily to loss of control, even though the wings were seen to break in mid-air.

Many eminent French physicians, including Prof. Moulinier, have investigated the effect of high altitude on the blood and heart action of aviators, and definitely conclude that in addition to the usual harmful effects of passage from a low to a high altitude, the sudden return from the high altitude to the ground, which in many cases takes but a few moments, has a very serious effect, that can be withstood for a short time only by men with extremely sound hearts and subtle arteries.

Dizziness, however, does not come from altitude alone. Orville Wright and many French aviators have been troubled by a physical effect of this kind as a result of making numerous short, sharp turns, as Johnstone and Hoxsey were accustomed to do, and many

WRECK OF A VOISIN AT RHEIMS, 1909

The picture indicates that imperfect lateral stability probably caused the accident.

novices who are likely to get "seasick" find that they become ill on a windy day when the machine pitches a great deal.

The recent fatal accident to Capt. Madiot, who was killed on Oct. 23, 1910, at Douai on a Breguet biplane, and that to Lieut. Willi Mente, who was killed at Magdeburg two days later on a German Wright, appear to have been due to loss of control alone. In both cases the aviators were observed to hesitate and fly uncertainly, and when the machines finally reached the ground, all wire stays, etc., were found intact.

In many cases where an aviator is affected by some form of heart failure, death has occurred before the ground was reached. This is supposed by many to have been the real manner in which Hoxsey died.

There seems now little doubt that in many cases, especially after a long run, an aviator is likely to become tired and nervous and finally so affected by vertigo and possibly fainting, that he loses his presence of mind, mixes up the controls and falls.

WRECK OF THE BLÉRIOT 80 HORSE-POWER MONOPLANE AT RHEIMS, 1909

This was due to fire, as great a danger to aeroplanes as to other craft. Note the motor and the charred propeller. M. Blériot was bruised and burned.

For all ordinary cases of this kind, the presence of two aviators capable of relieving each other would be a wise precaution.

To avoid the altitude effects, men with weak hearts should never fly above 1000 feet, and the quick downward swoops from high altitudes that have so entertained the public of late should be discouraged.

In accidents due apparently to loss of control, there is, of course, the possibility of a breakage in the controlling system itself. A wire may snap or a rudder become jammed with very serious consequences. Such care is taken, however, in the construction of most machines, and aviators themselves usually inspect their machines so thoroughly, that accidents due to this source are reasonably avoidable, and when they do occur indicate only negligence.

THE 1909 BREGUET BIPLANE JUST AS IT STRUCK THE GROUND HEAD-ON AT RHEIMS

M. Breguet, who can be seen plunging from his seat, escaped miraculously without any serious injuries. If he had been sitting in front of the motor he probably would have been killed.

2.

Collisions of aeroplanes, with obstacles when landing, starting or in full flight, are of frequent occurrence, and two aeroplanes have been known to collide in mid-air, but the results of such accidents are rarely fatal, although the machines may be totally wrecked. They are as avoidable as collisions in any other form of locomotion, and it is certain that the collision of two aeroplanes headed towards each other in mid-air is much less likely than that

LE BLANC'S 100 HORSE-POWER RACING BLÉRIOT AFTER STRIKING THE TELEPHONE POLE ON LANDING

Le Blanc was on the last lap of the Gordon Bennett race when a sudden leakage of fuel caused him to descend. No sufficiently clear space was available and he crashed into this obstacle with terrific force.

of two automobiles in like circumstances on a road, because of the greater freedom of movement that is available.

The tragic accident to Hauvette-Michelin at Lyon on May 13, 1910, was said to be due to the fact that his Antoinette collided with a pylon, and many other such accidents have happened, though not always with as serious consequences. They point merely to the importance of having a large, clear ground to start from and land on, a provision that is as necessary for aeroplanes as the Ambrose Channel is for the "Mauretania."

3.

That many serious breakages occur from landing too heavily is merely to say that the effect of a fall is collision with the earth. If the aeroplane is too heavily loaded and its speed not high enough to give a "tangential landing" then the shock of impact with the ground may do a great deal of damage from the breakage of a chassis to the complete smashing of the machine; but it has been actually found in practice that if the aviator is strapped in and the aeroplane well designed, he will suffer only a few cuts and bruises.

The wreck that happened to Brookins at Belmont Park when about to start in the Gordon Bennett was due entirely to the fact that the machine had not enough velocity to support the heavy loading and the chassis was too weak to stand the shock of landing. Had the machine had a lighter loading and a stronger chassis, the sudden stoppage of the motor would probably have had no serious effect.

The avoidance of accidents of this kind lies in doing away with the heavy loading, or else in landing at a high enough velocity by keeping the motor running, as is done with many of the high-powered Blériots.

4.

Turning in an aeroplane and especially in one fitted with a Gnome motor, requires a great deal of skill and much practice. It is said abroad that over 75 per cent. of the accidents that happen to novices are due to a sudden fall as a result of a false manœuvre in turning.

Whatever the nature of these accidents, however, they are avoidable only by the acquirement and constant exercise of that ordinary amount of skill that the obtaining of a pilot's license is supposed to require.

5.

Aeroplanes, especially those with large lifting tails like the Farman, are likely to lose headway when the motor suddenly stops.

THE RESULT OF LOSS OF BALANCE DUE TO RISKY FLYING
The wreck of Lefebvre's Wright machine.

Whether this results in a serious fall or not depends altogether on the skill of the aviator. With a fair amount of presence of mind and a high enough altitude the sudden breaking down of the motor need have no serious consequences. If it is very gusty, however, other effects may take place and complicate the descent.

The habit of many aviators, notably Paulhan and Leblanc, of flying "tail high" is not so much a matter of gaining speed by a reduction of the angle of incidence, as it is a measure of safety that in case the motor stops suddenly, the machine will at once tend to dive. Fortunately accidents from loss of headway are becoming more and more rare, but they still constitute a large percentage.

Losses of headway, due to the breakage of any tail piece or the jamming of the elevation rudder in the ascent position are likewise rare, although they are likely to happen and are avoidable only by structural perfection and strength.

A Wrecked Farman Biplane at Brooklands

Evidently the surest and safest provision against motor troubles is to equip the aeroplanes with two motors, each alone powerful enough to keep the machine in flight.

One of the most progressive indications of the appreciation of the importance and value of this disposition is the prize of $15,000 that is generously offered through the *Scientific American* by Edwin Gould, to be awarded for the best performance of an aeroplane equipped with two separate power plants.

HOXSEY PLUNGING TO HIS DEATH AT LOS ANGELES

6.

Many accidents, notably those to Delagrange and LeBlon, were due to so great a weakness in the apparatus that the increased pressure due to an ordinary turn, a passage between gusts or a gyroscopic effect, caused a breakage of the wings. An aeroplane must be designed to stand much higher pressures than those alone necessary for support. The air is very variable, and even on a relatively calm day there are likely to be "holes in the air," and the passage of an aeroplane through these regions causes conditions of pressure that must be resisted by additional strength in the machine. Practically all the breakages that occur in mid-air are due to insufficient strength to resist the variable air pressures that are met, or the peculiar and sudden forces caused by the gyroscopic action of large rotating motors. Only the strongest machines can be flown with safety on a windy day.

The accident to Rolls appears to have been due entirely to structural weakness. Rolls was flying a French Wright biplane, to which a rear horizontal surface had been added. But the spars designed to hold this surface were much too weak and they snapped when strained by a sudden gust.

Sommer, Farman, Paulhan and Tellier are but a few of the French constructors who fully realizing the great strains an aeroplane is put to, are bending all their efforts to obtain a great strength and solidity of structure. Aeroplanes must be carefully designed and calculated with a large co-efficient of safety.

There are innumerable machines flying to-day where not only no co-efficient of safety exists but where the materials are constantly worked at their elastic limit. The fatigue of materials appears to be ignored, and it seems profitable to do so—until the fatal breakage.

Materials, whether wood or steel, are altered after a time, by oxidation, changes in temperature and repeated vibration. Glued joints are at the mercy of humidity, as is the tightness and strength with which the plane covering fits to the frame. Metal pieces are greatly affected by a combination of magnetic phenomena, changes of temperature, and repeated vibration until after many million such vibrations the metal undergoes an allotropic transformation, or passes from the fibrous to the dangerous crystalline state. This is recognized in railroading practice, and even though no breakages actually occur, the vibrating parts of locomo-

A SNAPSHOT OF THE TEARING AWAY OF THE WINGS OF THE ANTOINETTE CARRYING LAFFONT AND POLA, AN EXCELLENT EXAMPLE OF THE EFFECT OF CENTRIPETAL FORCE

Note that the rear elevation rudder was turned up, i. e., the machine was about to be brought back to the horizontal. The propeller is in motion.

tives and cars are always replaced after they have run a certain allotted number of miles. It would be wise to adopt this practice in aviation.

The number of aeroplanes that are built and flown in which the construction is weak and unsafe is fortunately rapidly decreasing. But there still exist aeroplanes of so poor a structure that to attempt to fly in them is, to express it mildly, a very risky matter. At the recent exhibition of aeroplanes in New York City the author had occasion to inspect a biplane that had been constructed by an American firm for a well-known English aviator, and found that one of the wooden spars, leading out to the rear Farman type stabilizing cell, had a large knot-hole about at the center, where the bending moment was greatest, that reduced the effective cross section of the member to almost one-fourth of what it was supposed to be.

Accidents in mid-air to aeroplanes of such a structure are to be expected.

7 and 8.

The sudden dives that are frequently observed and that the aviators who experience them are positive do not result from any false rudder movement are indeed hard to explain. Whether in motor flight or in gliding flight, aeroplanes are again and again seen to pitch forward suddenly and dive towards the ground, as if the supporting power were annulled. Frequently aviators are able to correct this sudden plunge, but unfortunately they are sometimes taken unawares and a fatal drop to the ground results. One fact, however, stands out quite clearly, and that is that *accidents of this kind usually occur in a gusty wind.*

To upset suddenly a mass of the size of an aeroplane requires a considerable force. The gyroscopic force of a rotating Gnome must certainly be appreciable, but it is an open question whether it is considerable enough to jerk the aeroplane down in the manner observed. The effect of this gyroscopic action would more likely be a straining and breakage in the framework itself, and manifest itself as an internal force. To upset the aeroplane, however, some very large external force must act.

On an aeroplane in flight there is no source of external force other than the pressure of the air itself.

In Part I., Chapter V., the characteristics of the movement of the center of pressure on an aeroplane surface are clearly given. It is definitely known, now, that when an aeroplane is suddenly moved from a low angle of incidence to a still lower one, the center of action of the supporting force moves rapidly to the rear. If this movement is not at once counteracted by the elevation rudder, the aeroplane will be thrown out of equilibrium, because the supporting force will act *in back* of the center of gravity. This will cause a rotating force equal to the weight of the aeroplane acting

CHAVEZ STARTING FROM BRIGUE FOR HIS TRANS-ALPINE FLIGHT with a lever arm that is the distance between the point of action ot the supporting force (c. p.) and the center of gravity (c. g.). This force will turn the rear of the machine up and the front down, and cause the aeroplane to dive, and will do so as suddenly and in as great measure as the angle of incidence is changed. The lower the angle and the greater its sudden additional lowering, the greater will be the movement of the c. p. and consequently the more powerful the disturbing force. The cause of this movement is the pressure of the wind striking the surface of the plane and jerking it down in front.

It is known that in a high and gusty wind *the direction of the wind changes often and very suddenly.* Assuming then that we have an aeroplane moving at an angle of incidence of 5 degrees in a horizontal region of air, if in the nature of a sudden gust. this air region changes to one that is moving downward at an angle of 5 degrees below the horizontal, then the angle of incidence of the aeroplane will as suddenly drop from 5 degrees to 0 degrees.

It must be borne in mind here that the angle of incidence is the angle between the chord of the plane and the relative air current, and that the velocity of the wind itself is immaterial, since it only affects the motion of the aeroplane with respect to the earth, the aeroplane moving through the air at its ordinary velocity.

In this sudden drop from an incidence of 5 degrees to one of 0 degrees, the c. p. would jump back about 2 to 4 feet on a large plane. if the experimental data and facts upon which this is based are at all reliable. We then have a force equal to the weight of the machine, suddenly applied with this large lever arm. The natural consequence, if this force is permitted to act for a fraction of time, is the destruction of the balance and a dive downward. Incidentally it may be pointed out that if the wind were in the rear of the aeroplane, a sudden *upward* gust would have the same effect.

If the aviator is taken unawares, and the change in wind direction very pronounced, the machine will suddenly dive downward and plunge to the ground. On a Wright machine the effect would be to throw the aviator forward on the levers and thus fur-

HAMILTON ON HIS CURTISS BIPLANE, TRAVELLING FROM NEW YORK TO PHILADELPHIA, JUNE 13TH, 1910

The semaphores indicate the passage of the train from which this photograph was taken. Great steadiness was displayed the entire trip.

ther accentuate the dive—viz.: Hoxsey. On a Blériot it would throw him on the *cloche,* or if great enough pitch him headlong out of his seat—viz.: Moisant.

9.

There is one other type of accident that has puzzled aviators as much as the sudden dives—that is the collapsing of the planes of a seemingly strong machine at the moment when it is recovering

WILBUR WRIGHT AT ROME

from a long downward dip, in order to land tangentially. (See No. 1 in the diagram p. 314.)

Probably no other kind of accident is so unexpected and apparently so impossible of explanation. Again and again, Chavez, Blanchard, Laffont and Pola, being only a few of the victims, the aeroplane when just about to turn the arc with center at A (see diagram on p. 314) is seen to quiver for a moment and then the planes are torn away upward from the body and the entire mass crashes to the ground. No other kind of accident is so relentless in its result.

CURTISS PASSING STORM KING ON HIS HISTORICAL ALBANY TO NEW YORK FLIGHT, MAY 29TH, 1910

Not an accident occurred on this skillfully executed trip.

An explanation is hard to find and though one is given here, decision as to its final value is reserved until more is learned on this highly important subject.

The sudden breakage of the planes is evidently due to an enormously sudden increase of pressure on them.

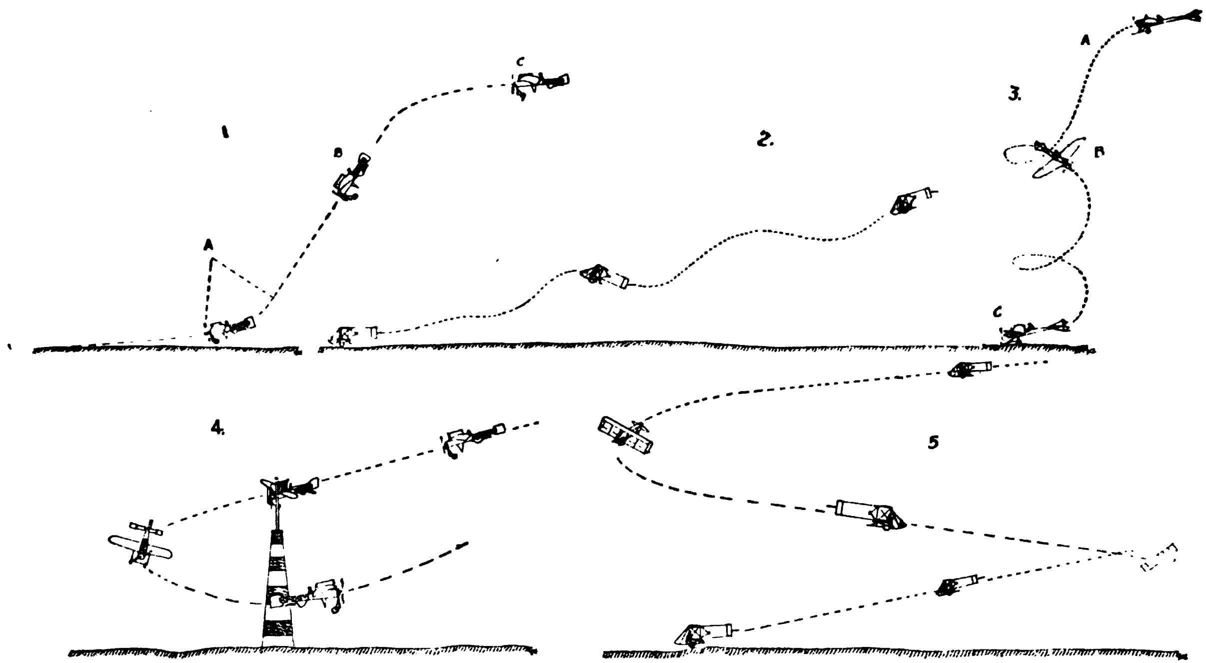
It is actually known that accidents of this kind occur only after long and steep "dips" or after short "dips" on a very windy day.

In the diagram on p. 314 is represented an aeroplane making a steep dip. At B the aviator stops the motor and starts to make the dive. and when he gets anywhere within 15 to 150 feet of the ground, depending on his "nerve," he suddenly sets the elevation rudder for ascent, which causes the machine to describe a curved trajectory with center at A, and a radius often as small as 100 feet. The motor is then re-started and the aeroplane travels along a little below the horizontal until finally it lands "tangentially" and the public present applauds the thrilling performance, little realizing its immense danger. As it dives from B the aeroplane gains enormously in velocity, depending altogether, of course, upon how steep the dive is. If at B the velocity is 65 miles an hour and the fall over 800 feet, the velocity at A can easily have risen to 70 miles an hour, if not more, and the momentum of the machine is large. The increased velocity makes the action of the rudders much stronger, due to the increased pressure.

There exists then at the turn a mass of, let us say, 900 pounds, moving at 70 miles an hour, and about to describe the arc of a circle with center at A and a radius possibly 100 feet.

Any mass in order to describe a circle must be constrained to its orbit by a force acting towards the center on the body and from the outer region which is the centripetal force of the familiar form $\frac{mv^2}{r}$.

Computing the centripetal force for this 900 lb. aeroplane describing this orbit, there is obtained for it *the value of almost* 3,000 *pounds or more than three times the normal pressure on the planes.* It is little wonder that they tear apart, since this is acting up under the planes to hold the machine towards A.



DIAGRAMS OF SOME METHODS OF FLYING

1. A steep "Volplane." At *B* the aeroplane is falling with motor cut off. At *A* the turn is made in order to land tangentially. 2. The "ocean-wave." Wilbur Wright coasting down. 3. The "spiral dip," a succession of sharp dives and turns. 4. A skillful turn by Le Blanc, showing how he dives on turning, thus gaining speed. 5. The safest way to "volplane;" a long series of descending circles.

This enormous force is as great in its effect as if each side of the plane hit a stationary obstacle at this point. The significance of this centripetal force becomes at once apparent. It is interesting to note in addition that accidents of this kind do actually occur much more frequently to monoplanes than to biplanes. The nature of the bracing explains this.

THE CALM OF THE UPPER AIR IS AT TIMES SERENE
Brookins at Indianapolis, June, 1910.

REAL FLYING WEATHER

Note the calmness of the water and the sailing yachts in the distance. Johnstone in his Wright biplane, hovering over Boston Harbor.

In conclusion it may be said that while accidents of the first six types are fully recognized and therefore more and more avoided, accidents due to the sudden shifting of the center of pressure and to the centripetal force when turning at the bottom of a dip are not yet generally realized and every effort should be bent to their ultimate abolition.

The remedies for these two causes are clearly evident and certainly capable of execution. Two immensely important facts stand out:

1. *Flying in gusty weather conditions is dangerous.*

2. Descending by means of the long, steep "dip" is still more dangerous.

To avoid (1) more care should be exercised by aviators in flying, when conditions are really bad.

To avoid (2) other methods of descent indicated on p. 314 should be used, and the long "dip" should be absolutely prevented or the strength of the machines very greatly increased.

Most of these accidents in aviation, therefore, are avoidable if flying in spirals and steep volplanes for the purpose of thrilling the public is stopped, and if aviators acquire and use better judgment in interpreting the conditions of the weather.

De Lesseps Crossing the Channel on His Blériot XI., May 21st, 1910

CHAPTER XV.

THE VARIABLE SURFACE AEROPLANES

Conditions of starting and landing are the most pronounced limitations to high speed, and it is now becoming recognized that the aeroplane that is able to fly slowly when near the ground and faster and faster in the air, at the will of the pilot, is to mark as

ELY ABOUT TO ALIGHT ON THE CRUISER "PENNSYLVANIA," IN SAN FRANCISCO HARBOR, JAN., 1911

great an advance in aviation as did the introduction of transverse control by the Wrights.

A simple means of effecting this desired range of velocity is to alter the size of the surface itself. It is easily demonstrated from the theory of the aeroplane (see Part I.) that as the velocity is increased, the lifting pressure on the planes also increases and to so great an extent that a much smaller surface is required for support. Conversely, if the supporting surface itself is decreased, the resistance to motion becomes much less and the velocity at once increases to that required for support with the smaller plane area. So that once the aeroplane is in flight, a great increase of velocity is obtainable by a gradual reduction of the surface area, and in order to decrease the speed to land with safety all that is necessary is to spread out the surface again to its maximum. The limiting factor in this, other than the amount of reduction possible, is the pure head resistance of the framing, which, of course, will not only be the same but will be greatly increased by the higher speed.

ELY'S CURTISS JUST AFTER LANDING ON THE CRUISER

Note the single plane elevator and ailerons at the rear of the main cell. Ely, later, took to flight from the cruiser's deck and returned to his hangar.

Actual computation, on an aeroplane whose maximum surface is 300 square feet and lowest speed of support 50 miles an hour, shows that with the same power upon reducing the surface to 150 square feet the velocity will rise to over 70 miles an hour. The degree with which this could actually be attained in practice can only be determined by actual experiment, but that it is in great measure possible is hardly open to question.

Many means of reducing the surface of an aeroplane have been tried. The commonest suggestion is to cause the tips to turn back horizontally and fold under the central section of the surface, very much as a bird folds its wings. Another method is to have the outer sections slide in towards the center, thus greatly decreasing the span but leaving the chord constant. Most of these methods

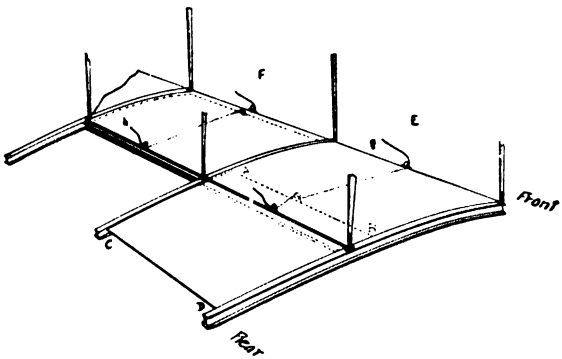


DIAGRAM ILLUSTRATING THE METHOD OF "REEFING" AEROPLANE SURFACES, SUGGESTED HERE

are at present found to be structurally impractical, and in addition to this, reduction of span alone is inadvisable because it reduces the aspect ratio of the plane and therefore causes it to be less efficient.

THE CURTISS HYDRO-AEROPLANE SKIMMING THE SURFACE AT 40 MILES AN HOUR BEFORE RISING

The simple boat-like body under the machine supports it on the water, and as the speed increases it gradually rises entirely clear of the surface. This new development augurs much for the future. It is over water that the aeroplane will find its greatest usefulness.

A method that is structurally feasible and that has many advantageous features, is here suggested.

In the diagram on p. 321 is shown a section of the lower plane of a biplane, illustrating this method of surface reduction. The front section of the plane between the vertical struts is made double surfaced, a considerable clear space being left between the two surfaces, into which the thin surface ABCD can slide. The large I beam ribs are projected out to the rear as shown, and are so constructed that ABCD slides or rolls in a groove on each side.

In panel E, the movable surface is shown extended to the rear.

SIDE VIEW OF THE CURTISS HYDRO-AEROPLANE, SHOWING SINGLE PONTOON

Note the single plane elevation rudder at the front, the flap at the rear of the fan-tail, and the ailerons on the rear posts of the main cell. These are features of the latest Curtiss machines.

If cable *g* is pulled, the surface slides into the space left for it and takes the position shown in panel F. If cable *h* is now pulled the surface will again slide out. There are innumerable ways in which the control of this motion may be effected, but the movements are, combined in such fashion that the surfaces all slide in and out together, in an equal amount, unless an unequal motion on opposite sides is to be used for transverse control, as it easily could be.

The enormous advantage of this method of surface reduction other than its structural simplicity, is that in reducing the surface, the span is kept constant and the chord only decreased, so that the aspect ratio is greatly increased and the aeroplane rendered much more efficient. The limit of the reduction is a little more than half, as some clearance will always be necessary.

There is one point, however, that will need very careful con-

Curtiss in Flight After Rising From the Water

sideration and that is the balancing of the movement of the center of pressure as the reduction takes place.

With the present motors and types of aeroplane structure available, there is little doubt that by use of this method, a racing machine capable of making 85 to 90 miles an hour could be designed with ease.

THE END.

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